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Evaluation of the Potential of PEAT IN ONTARIO

Energy and Non-Energy Uses

by

Monenco Ontario Limited

1981

Ontario

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MONECO ONTARIO LIMITED PEAT FACT SHEET

METRIC CONVERSIONS

1 ft	=	0.305 m
1 acre	=	0.405 ha
1 lb	=	0.454 kg
1 ton	=	0.907 t (metric)
1 Btu (Int)	=	1055.06 J
1 Btu (Int)	=	1.055 kJ
1 Btu/lb	=	2.326 kJ/kg
1 cal	=	4.1868 J
1 Btu	=	251.997 cal
1 Btu	=	0.293 Wh
1 lb/ft^3	=	16.018 kg/m^3

FUEL OIL DATA

1 BBL (statistical)	=	42.0 gal U.S.
1 BBL (statistical)	=	34.97 gal Imp
1 m^3	=	6.29 BBL
1 gal (Imp)	=	0.1605 cu ft
1 cu ft normal fuel oil*	=	61.50 lb
1 lb normal heavy fuel oil*	=	18,640 Btu
1 tonne normal heavy fuel oil*	=	6.39 BBL

PEAT AS FUEL

(Approximate figures—good grade fuel as a 50% moisture content—wet weight basis)

1m^3 of any peat	=	130-1300 lbs or 60-600 kg
1 m^3 of fuel peat	=	770 lbs or 350 kg
1 tonne of fuel peat	=	2.86 m^3
1 m^3 of fuel peat	=	3,850,000 Btu
1 tonne of fuel peat	=	11,000,000 Btu
1 tonne of heavy oil*	=	41,000,000 Btu
1 tonne of heavy oil*	=	3.7 tonnes of fuel peat
1 tonne of heavy oil*	=	10.7 m^3 of fuel peat
1 BBL of heavy oil*	=	1.67 m^3 of fuel peat

*Bunker 'C', commonly used for power generation.

COMMON MOISTURE CONTENT OF PEAT

Peat Type	% of Wet Weight
In situ	85-95
As delivered (solar-dried, milled)	45-55
As fired	10-30
Briquets	10-25
Sods (solar-dried)	30-40

COMPARISONS OF PEAT WITH OTHER FUELS

	ASH (% of dry weight)	SULPHUR (% of dry weight)	COMMON MOISTURE CONTENT (% of wet weight)	COMMON SPECIFIC GRAVITY kg/m^3	COMMON SPECIFIC GRAVITY lbs/ft^3	As Received Gross CALORIFIC VALUE kcal/kg	As Received Gross CALORIFIC VALUE Btu/lb
Wood (Pine, spruce)	0.4-0.6	—	42	320-420[1]	20-26[1]	2970	5340
Fuel Peat	1-10	0.1-0.2	50	300-400	19-25	2775	5000
Lignite (Sask)	9	0.4	37	1120-1280	70-80	3890	7000
Coal (thermal)[2]							
Sub-bituminous (Alta)	16	0.5	20	1200-1360	75-85[3]	4440	8000
Bituminous (Eastern)	13	1.5	6	1200-1440	75-90[3]	6140	12500
(Western)	16	0.6	7	1280-1440	80-90[3]	6390	11500
Heavy Oil	0.3	2-2.8	0.1	920-990	58-62	10350	18640

(1) Seasoned @ 10% moisture. (2) Coal analyses taken from typical operating mines. (3) In-place approximate values.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the assistance of Messrs. G.A. Jewett and P.G. Telford of the Ministry of Natural Resources, Mr. H.G. von Cube of the Ministry of Northern Affairs and Miss J. Lam of the Ministry of Energy in the preparation of this report. As well, the efforts of Mr. E. Lappalainen of the Finnish Geological Survey were most appreciated in arranging visits to the various laboratories, peat production and peat utilization operations in Finland.

This report was prepared by Monenco's Peat Group specialists Messrs. G.W. Mankinen, E.O. Korpijaakko, J.A. Fraser, S. Banovac and J. Riley. Other specialist input on economics was provided by the Company's Management Sciences Group, by Messrs. M. Wilton, D.H. Stevenson, and P.W. Martin. Special assistance on peat processes was provided by the Ontario Research Foundation, in particular by Messrs. T. Gallo, E.A.N. Sugen, M.P. McKim and Mrs. E.A. Smith.

ERRATA FOR OCCASIONAL PAPER NO. 7

Evaluation of the Potential of Peat in Ontario
Energy and Non-Energy Uses
by Monenco Ontario Limited

Peat production costs should have been expressed in terms of dollars per gigajoule (eg $3.71/GJ) and not in terms of dollars per megajoule (eg $3.71/MJ).

See: Executive Summary, page 2
Table 4-4, page 77
Table 4-6, page 81
Summary of Peat Processing Technology, page 111

In Table 4-25, page 103, $5.40/GH should be $5.40/GJ.

FOREWORD

In 1980, the need for a state of the art review of Ontario's peat resources and their potential energy and nonenergy uses was recognised almost simultaneously by the Ministries of Natural Resources, Energy, and Northern Affairs. A committee with representatives from each of the ministries was established to design and appropriate program of study and to oversee its implementation. The committee was made up as follows:

Mr. G.A. Jewett (Chairman)
Executive Co-ordinator
Mineral Resources Group
Ministry of Natural Resources

Miss J. Lam
Policy Advisor
Conventional Energy Group
Ministry of Energy

Mr. H. von Cube
Senior Policy Advisor
Strategic Planning Secretariat
Ministry of Northern Affairs

Dr. P.G. Telford (Project Manager)
Energy Policy Advisor
Mineral Resources Group
Ministry of Natural Resources

It was agreed that the Ministries of Energy and Northern Affairs would fund the study with the Ministry of Natural Resources acting as manager. The Ministry of Natural Resources also assumed responsibility for ensuring publication of the results of the study, including the allocation of funds necessary for this purpose.

A contract for the peat study was awarded to Monenco Ontario Limited in March 1981. Their final report, submitted on September 1st, 1981, formed the basis of the present publication. This report provides the first overall review of the possible uses and the opportunities for development of one of Ontario's most significant natural resources. We hope this will stimulate the private sector to consider peat as a serious contender to meet Ontario energy needs of the future.

EXECUTIVE SUMMARY

A. CONCLUSIONS

PEAT RESOURCES

1. Information on the extent of the peatlands of Ontario is quite varied. Previous information published by Simard (1972) showed only 200 hectares of peatland exploited in Ontario and no peatland was listed as being surveyed or determined to be potentially exploitable (see Table 2-1). According to Tibbetts (1980) the potential/inferred peat resources of Ontario were estimated to be 16 million hectares or 27.6 billion tonnes (at 50% moisture content) and the portion of peat resources measured was estimated to be 62 thousand hectares or 135 million tonnes (50% moisture content) (see Table 2-3). This represents only 0.4% of the total estimated peatland at the time of publication of this data.

2. For purposes of the current investigation the peatland area of Ontario was measured from topographical and engineering geology terrain studies maps and is estimated to be about 26 million hectares (Table 2-16). About 9.9 million hectares, corresponding to approximately 41.7 billion tonnes of peat (at 50% moisture content), is estimated to occur south of the southern limit of permafrost (see also Table 2-19). This is roughly equivalent to 72 billion barrels of oil if *ALL* of the peatland were considered available for energy production. Plate 1 is a reduced copy of the "Generalized Peatland Distribution Map" produced during the course of the present study.

3. If the 62 thousand hectares of Ontario peatland reported surveyed (Tibbetts, 1980) is reasonably correct, then only about 0.2% of the total peatland has been surveyed. If the 200 hectares reported as exploited (Simard, 1972) is accurate, then less than 0.001% of the total peatland area is under mining.

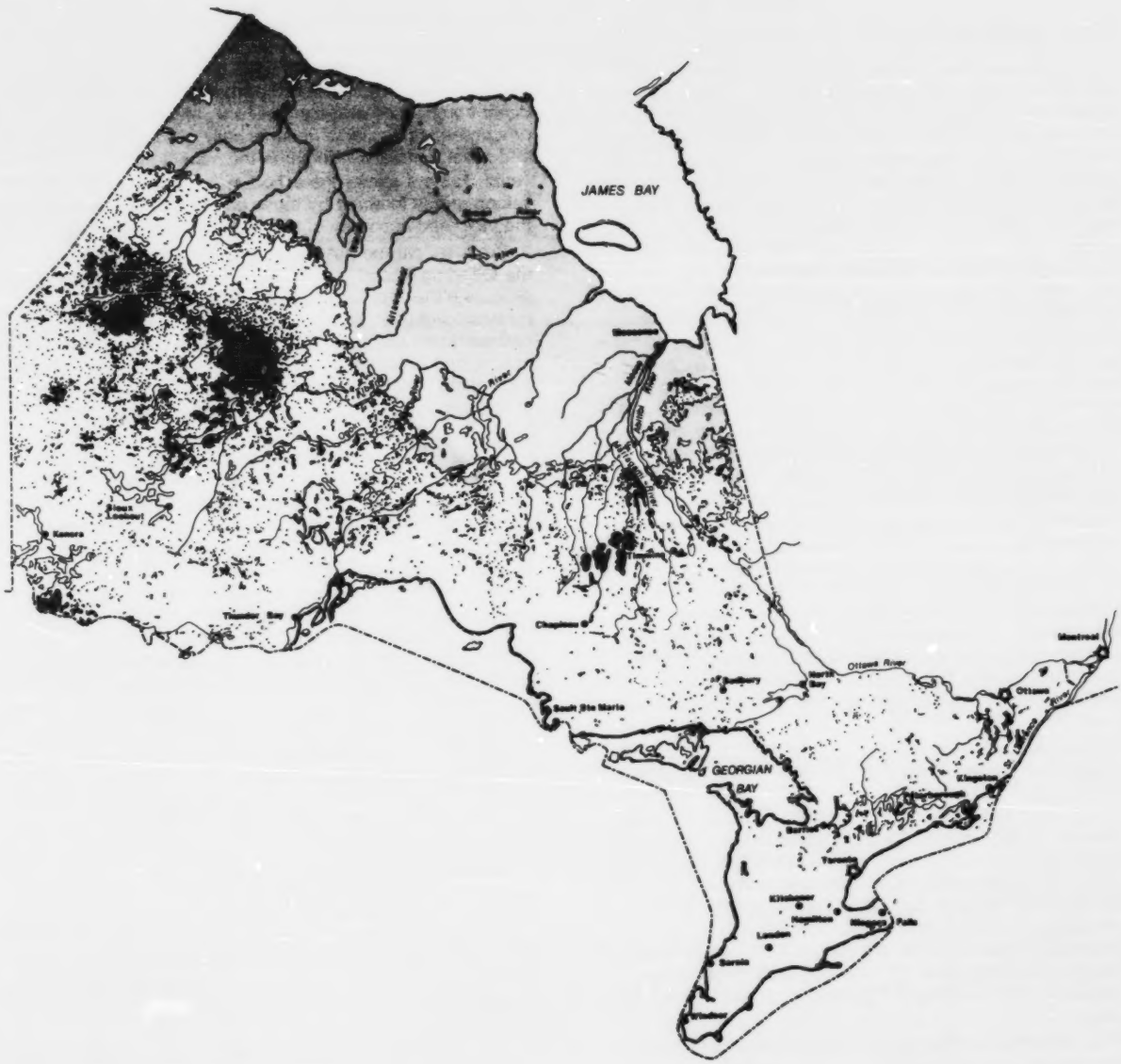


PLATE 1. GENERALIZED PEATLAND DISTRIBUTION IN ONTARIO.

4. Internationally published data (Kivinen *et al.* 1980) places Canada first with the world's largest peat resources, about 170 million hectares, followed by the U.S.S.R. with 150 million hectares. The total of 26 million hectares of peatland places the Province third in world statistics (excluding the rest of Canada), together with Indonesia (see Table 2-3).

5. The survey of the literature on the physical and chemical properties of Canadian and Ontario peats indicated that the values compare well with the published values for northern European and Irish peat. It is expected that further peatland surveys and sampling will confirm the suitability of Ontario peats for both horticultural and fuel peat production, as far as peat quality is concerned.

6. Although the published information on peat in Ontario is voluminous, it covers mainly special research-oriented or site-specific works and does not give a comprehensive account of the general distribution of the different peatland and peat types. Standard, uniform classification systems have not been used. A modified von Post system is recommended for peat classification as well as that proposed by Jeglum *et al.* (1974) for peatland classification for future peatland inventory work in Ontario.

PEAT MINING

1. Conventional peat mining methods, such as the milled and/or sod peat systems used in Finland, appear well suited to Ontario conditions, at least for the portion of the Province south of the southern limit of permafrost. Irish mining systems, featuring narrow gauge rail transport, are expected to present difficulties in Ontario because of the more severe winter conditions. Wet mining systems and associated processes are not yet commercially proven and require considerable research and development. Wet mining has a current application for horticultural sphagnum peat production, however, low cost energy supplies must be available to economically dry the peat from 70% to 50% moisture.

Plate 2 summarizes the key activities associated with the various methods for mining peat as discussed in detail in Part 3 of the report. Although the wet mining methods, such as slurried peat and bulk excavation, simplify the mining process in terms of number of activities, and offer the potential of being carried out over a longer production season, one should note that the as-mined moisture levels are considerably higher, necessitating dewatering equipment.

2. Most of the self-powered mining equipment, such as tractors, are manufactured in Ontario and with certain modifications could be well suited for peat operations. All of the Finnish peat production machinery is compatible with these tractors and is recommended for use when Canadian-built machinery is not available. Ireland does not manufacture peat equipment for export and Russian peat equipment, while being suited to Ontario, is excessively large, heavy, and is generally not compatible with Canadian-built equipment.

3. Fuel peat is currently not produced in North America on a commercial basis, thus peat production cost estimates for Ontario have been based on costs experienced in Ireland and Finland as well as on other detailed studies prepared recently by Monenco in Canada. It is estimated that Ontario milled peat production costs will be in the range of $18.00 to $24.00 per tonne (at 50% moisture) and sod peat costs will be in the range of $31.00 to $40.00 per tonne (at 30% moisture) excluding costs for Hudson Bay Lowlands. More accurate production costs will require an actual mining operation or a demonstration mining project to be implemented and monitoring of the climatic, production and cost data.

4. A preliminary comparison of climate between Ontario and Finland was carried out based on climatic factors such as temperature, hours of bright sunshine, evapotranspiration, and moisture deficiency. The purpose of the analysis was to determine the suitability of the climate of Ontario to peat mining and also to estimate possible peat production rates, using conventional peat mining technology. The climate of northwestern and central Ontario was found to be very similar to that of Finland for the May to September peat mining period. It is expected that peat production rates achievable in the northwestern and central regions will also be similar to Finnish rates.

An approximate ranking, in terms of peat production potential, was made for various areas of the Province based on consideration of the various climatic factors. The ranking showed southern Ontario to be the most favourable (see Plate 3-1), followed by the Sudbury (central Ontario) and the Rainy Lake-Kenora-Red Lake regions with about equal potential regarding suitability for peat mining. Although the most northerly of the eleven weather stations considered, Lansdowne House was the next most favourable location, followed by New Liskeard and Atikokan areas, and then Kapuskasing, Nakina and Moosonee in that order.

PEAT PROCESSES

1. Peat dewatering and processing technology is undergoing intensive development in the U.S.A., Finland, Sweden and Canada. At the present time, only small tonnages of peat are consumed outside the traditional applications for direct combustion and agriculture. A few alternative processes are available commercially at the present time, and several more will come on the market in the next five years. Table 1 shows the schedule for peat technology development as forecast by those engaged in the work and the indicated accuracy of their capital cost estimates.

2. Products can be obtained from peat by a combination of the following operations: mining, which delivers to the process either wet bog material or solar-dried solids; pretreatment, consisting of mechanical pressing, wet carbonization and thermal drying either singly or in combination; and processing, in the course of which a variety of treatments yield useful products. Plate 3 shows the major processing routes available to produce a desired peat product.

3. In order to eliminate limitations due to climatic, environmental and production-scale factors, wet mining methods have been proposed, which deliver bog material to the processing plant at 80-97% moisture content. The technologies processing wet mined peat are distinct from those utilizing solar-dried material. Several of these are in an early stage of commercialization. However, wet mining technology has not received sufficient attention, and the economics of it are not known with any confidence.

Two experimental processes, under development at IGT and Dynatech R & D Corporation, employ anaerobic digestion of wet mined peat slurries to produce substitute natural gas (SNG).

Machinery is now available for mechanical dewatering of moss peat (I-R roller press) and/or fuel peat (Sulzer belt press) to 70% moisture on a moderate scale of production (50-100 tonne/day dry solids per unit). Thermal dryers will further reduce the moisture content to 50% or lower.

For large-scale production (minimum 200,000 tonne/year), the JP-Energy/Wheelabrator-Frye wet carbonization process yields from wet mined peat a uniform, pelleted or powdered solid fuel at 8% moisture. Its cost was estimated to be $3.67/MJ based on uncertain mining costs. The application being promoted for this product is substitution for residual oil in industrial boilers or other direct combustion applications.

4. The production of substitute natural gas from milled peat is being studied in experimental units at IGT (PEATGAS) and Rockwell International (CS/R Hydrogasification). The

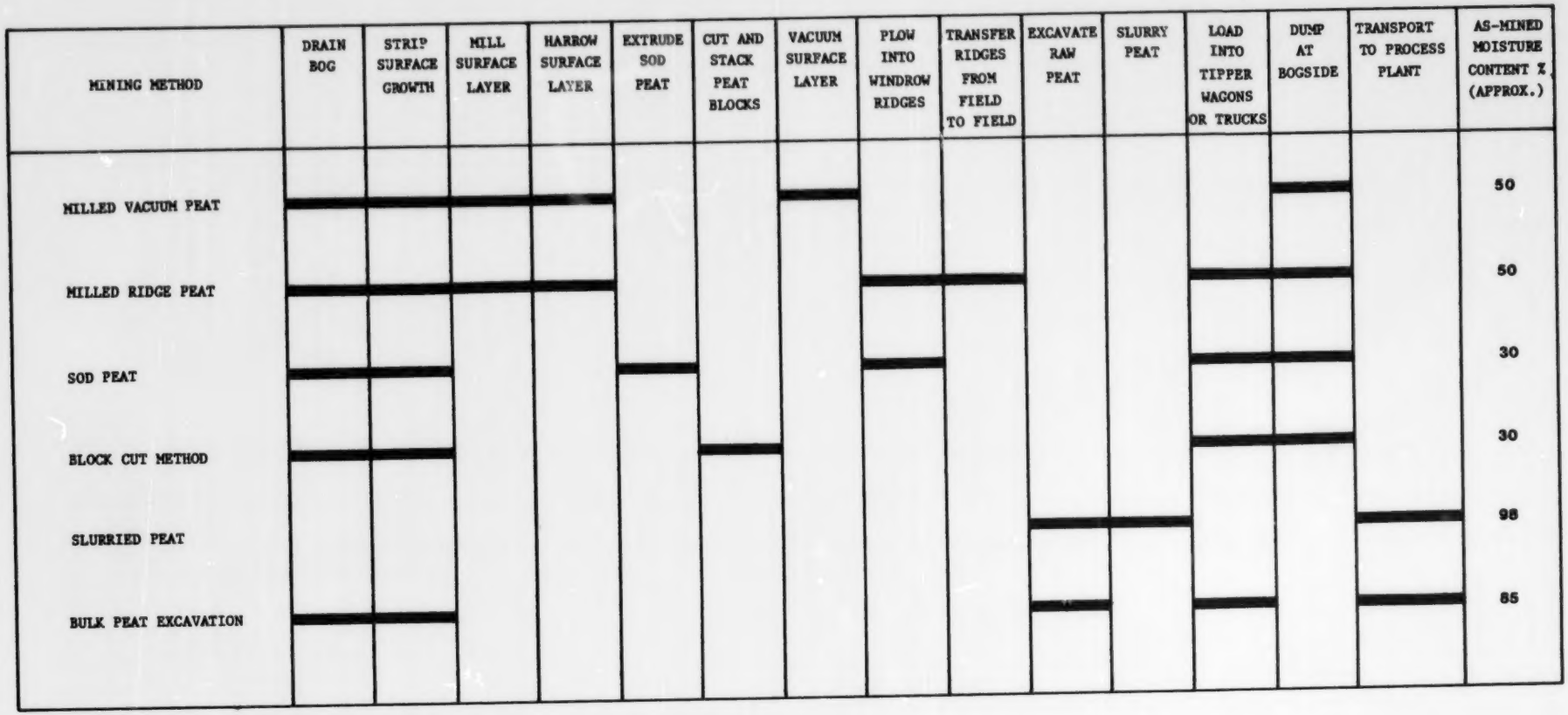


PLATE 2. PEAT MINING METHODS, MAIN ACTIVITIES.

TABLE 1. AVAILABILITY OF PEAT PROCESSING TECHNOLOGY.

Technology	Product(s)	Source	Maturity of Technology in 1981	1982	1983	Accuracy of Capital Estimate
Mechanical dewatering	~ 70% MC peat	Sulzer, Ingersoll-Rand	1			A
Thermal drying	Horticultural or fuel peat	Many sources	1			A
Drying and briquetting	Briquettes, ~ 15% MC	Outokumpu	1			B
Coke production	Metallurgical coke, BBQ fuel, feed for act. carbon	Outokumpu	1			B
		Karl Still	1			Available later
Heat treatment	Oil absorber	VAPO	1			Available later
Activation	Activated carbon	Karl Still	1			Available later
Boiler plant systems	Electrical and thermal energy					
—Injector burners		Many sources	1			B
—Pyroflow™ Combustor		Ahlström	1			B
—Fluidized bed combustion plant		Outokumpu	1			B
Wet carbonization	"PDF" solid fuel	JP-Energy/Wheelabrator	3	2		B
Wet pyrolysis	"K-Fuel" solid fuel	Koppelman/SRI	4	4	4	N/A
Wet combustion	Energy	Ontario Research Foundation	5	5	4	N/A
PEATGAS™	SNG or syngas or MBG	IGT	4	4	3?	C
CS/R Hydrogasification	SNG, benzene	Rockwell Int'l	4	4	4	C
Koppers-Totzek Syngas	Methanol	Peat Methanol Assoc.	2	2,3	2,3	A
MINO Syngas	Methanol	Studsvik, RIT		4	4	N/A
1 MW sod gasifier	Electrical & thermal energy	VTT	4	4,3	2	C
25 MW sod gasifier	Low-Btu gas	VTT	4	4		N/A
Direct liquefaction	Bitumen	Sherbrooke U	5	4	4	N/A
		RIT	5	4	4	N/A
Biogasification	SNG, pentanol	Dynatech	5	5	5	C
BIOTHERMGAS™	SNG	IGT	5	5	5	C
Vyrmethane	SNG	Vyrmetoder	5	4	4	C

State of development: 1. Operating plant(s)
2. First commercial plant in design
3. Ready for licencing
4. Development/Demo unit
5. Bench-scale, research unit

Accuracy of capital estimates: A Commercial venture reliability
B Detailed estimate
C Factored estimate
N/A Not available

former yields predominantly methane, but can be designed for synthesis gas production. The latter, operating at high hydrogen partial pressures, allows the optional co-production of benzene, along with the methane. Factored estimates for plant design were carried out for both processes to evaluate capital and operating costs and revenue requirements for 250 x 10^9 Btu/day installations. Neither process is expected to produce SNG at the price at which it is currently available in Ontario.

5. The composition and chemical reactivity of peat is similar to cellulosic biomass. This is recognized by several groups active in process development which are experimenting concurrently with biomass as well as peat feedstock. These processes are: BIOTHERMGAS (IGT), MINO (Studsvik-RIT), and VTT gasifiers.

It is important to be aware of these similarities in order to take advantage of potential synergism in future research expenditures.

6. Synthesis gas may be produced from peat by adapting coal gasification technology (Koppers-Totzek) or taking a fresh approach (Studvik). Syngas may then be converted to methanol by well established technology.

In the United States, a 614 tonne/day methanol plant, using Koppers-Totzek gasification of milled peat, is being designed for 1984 startup. The low cost milled peat to be produced at First Colony Farms in North Carolina will allow the production of methanol for U.S. $0.75/gallon (1981) with adequate return on investment (Peat Methanol Associates).

Optimization of the entire peat-to-methanol process-train led to the design of the 300 kg/h MINO process development unit, scheduled for startup in late 1982 (Studsvik, RIT, Sweden).

7. Peat can be carbonized by commercially available technology (Outokumpu) to form two products: coke for metallurgical purposes, or a partially carbonized char which serves as starting material for activated carbon.

Both of these products are known and used in Europe. The secretive nature of the activated carbon manufacturing industry would require close co-operation with one or more manufacturers before the potential of Ontario peat can be assessed in this application. The application of peat-coke in existing metallurgical processes would also merit further study, since interest in this product has been reported from export markets, e.g. Japan, Norway, Germany.

8. The direct combustion of peat in thermal and electrical energy production relies on well established technology which is applied in the U.S.S.R., Ireland and Finland. The scale of possible application ranges from household use through industrial boilers and district heating to power stations.

Industrial boiler plant systems burn sod peat in grate furnaces; milled peat is fired in suspension as a pulverized fuel. Fluidized bed combustion systems have recently been made available commercially by Ahlström and Outokumpu companies.

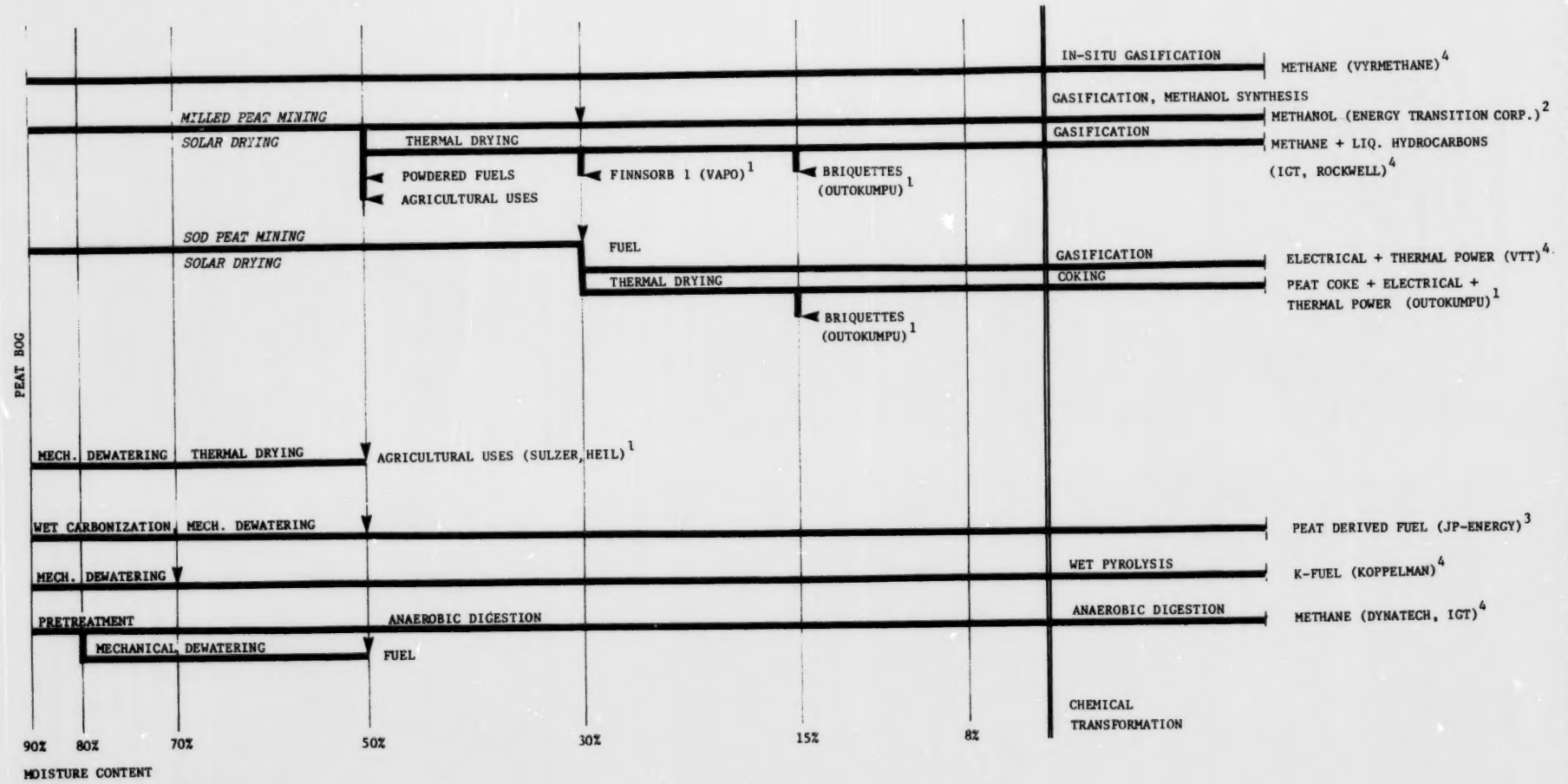


PLATE 3. PEAT PROCESS TECHNOLOGY.

Legend: 1. Plants in Operation.
2. Designing First Plant.
3. Feasibility-Study Stage.
4. Under Development.

POTENTIAL APPLICATIONS

1. Eight alternative potential applications of peat (scenarios) were selected for analysis, and the ability of the peat products produced in each scenario to compete in the marketplace with other competitive products was evaluated at a preliminary level. Certain qualifying remarks are to be considered when discussing the results of the preliminary analysis, and include:

- the analyses were designed to evaluate the potential of the alternative applications and should not be construed as detailed investigations e.g. a typical cost of peat was used, which may in fact be higher or lower in various parts of the Province,
- an actual bog-site location or demand center was not chosen, nor were actual haulage distances considered, rather a 30 km distance was assumed,
- typical values of competitive fuels were chosen, rather than geographically specific prices, and
- other items not considered in this evaluation of the alternative applications were: handling constraints (real or imagined); environmental (air, ash); and marketing programs including the education of the potential peat consumer.

2. It was determined that there exists in Ontario a market for the products produced for each application, however, some of the alternatives do not produce products which, at this time, are judged to be price competitive with the alternatives considered. Generally, those scenarios in which peat was used without significant upgrading were judged to be more competitive than those that involved significant upgrading of the peat.

3. Taking into consideration the above mentioned qualifying remarks, it was concluded that in the short-term, the following six of the eight alternative applications warrant more detailed investigation and the expenditure of effort aimed at commencing the utilization of Ontario's peat resources:

- Horticultural Peat Production for Agricultural Uses;
- Small-Scale Sod Peat Production for Space Heating (this is actively being studied by the Government of Saskatchewan);
- Sod Peat Production for Residential and Non-Residential Space Heating;
- Sod Peat Production for Industrial Process Heat Generation;
- Sod/Milled Peat Production for Use in District Heating;
- Sod Peat Production for Power Generation using a Small-Scale Peat Gasifier.

The other applications investigated, "Sod Peat Production for Coking" and Wet Mined Peat Production converted to a "Peat Derived Fuel for Power Generation" are expected to become viable as the associated technologies are developed and as market niches that can be efficiently filled by the products of these processes are identified.

4. In the application study of "Horticultural Peat Production for Agricultural Uses", it was suggested that a horticultural peat mine producting 30,000 tonnes of bagged peat for the Ontario and export markets would be a viable operation. The absence of such a plant at the present time may be due to one or more of the reasons discussed in Section 5.5.3, particularly the timing of cash flows and the cost of identifying a suitable bog.

5. In the application study of "Small-Scale Sod Peat Production for Space Heating" it was suggested that such an application is viable in the rural areas of Ontario. It is not expected that this scenario will develop of its own accord for two reasons: the first is that the potential users are probably not aware of the potential that exists for them to mine and use peat, and the second is that the cost evaluation of the suggested application is based on data extrapolation and not an analysis of an existing Ontario operation and is thus, subject to various significant uncertainties. In the "Recommendations" section several suggestions are made to remove some of the uncertainies associated with the various scenarios and to further evaluate their viability.

6. The application scenario entitled "Sod Peat Production for Residential and Non-Residential Space Heating" was judged to be viable, particularly for small communities in north-central Ontario. Reasons that this use might be slow to develop are that the potential consumer is probably not very aware of the resource and the use he could make of it, and fuel peat is not presently mined and used in such an application in Ontario. However, the potential for substituting peat for 80% of Northern residential and institutional fuel oil usage in selected areas could justify the effort required.

7. The application study of "Sod Peat Production for Industrial Process Heat Generation" suggested that the pulp and paper and cement industries at plants in Kenora and Picton respectively have the greatest potential to utilize peat of the industries examined. In particular, the large volumes of peat which would be consumed by individual plants could justify larger, more economic mining operations. In the "Recommendations" section further programs are outlined to encourage peat developments in this area.

8. In the discussion of the application "Sod/Milled Peat Production for Use in District Heating", it was suggested that this application is cost competitive with user generated heat, on the basis of the preliminary figures reviewed. The competitiveness of the district heating application is expected to improve as the cost of alternate fuels increases more rapidly than the cost of peat. To support this alternative the Province could carry out site studies to identify potential locations for a district heating plant.

9. The potential application scenario "Sod Peat Production for Power Generation using a Small-Scale Gasifier" suggested that several northern communities are potential users of peat in this application, particularly remote northern locations where electricity is generated by small diesel generators. The factors limiting the likelihood of this application being developed include the apparent lack of a sufficient demand (excluding demand presently price limited) and the fact that the gasifier technology is not fully proven. There are, however, several communities which are of sufficient size to establish demonstration projects, with a relatively small capital investment required. The "Recommendations" section contains several suggestions for further evaluations for this potential peat application.

ENVIRONMENTAL

The basic environmental concerns discussed in Part 6 of the report demonstrate that, with existing technology and certain developing peat technology, peatland development is not expected to cause severe or significant impact on the environment, however, experience in this area is still lacking and, particularly, developing technology needs to be monitored regarding its possible environmental impacts. The large peatland areas in Ontario have been virtually unused for peat mining and to alleviate environmental concerns requires careful research programs and monitoring systems (including background measurements) including a well planned system of guidelines and regulations to ensure their wise and orderly development.

It is expected the vast majority of peatland will never be required for exploitation even with extensive development of a peat industry in Ontario.

REGULATORY GUIDELINES

1. Regulatory procedures (see Part 7) are a complex matter and require research in depth into both the literature on the environmental effects of peatland drainage, mining and processing elsewhere, and into existing regulations in Europe and North America. A comprehensive listing of all the environmental effects and possible remedies and mitigative methods were beyond the scope of the present work. Close cooperation will be required between the governmental departments responsible for policy formulations as well as a committee or consultant responsible for the technical and socio-economic details. It is difficult to divorce policy and the actual technical details from each other. Close cooperation, it is hoped, will lead to development of a sound system which will enhance the utilization of peat, with a proper element of regulatory constraints to ensure an environmentally acceptable industry, without too constrictive regulations.

2. The Province of New Brunswick and the State of Minnesota are possibly the two most advanced areas in North America for formulation of policy dealing with peatland development. The Department of Natural Resources in both cases has, through committees and advisory groups, been active in developing policies in some cases leading to regulations. The Ministry of Natural Resources in Ontario currently administers the various Acts covering peat for energy and non-energy uses.

3. Comments on term, size of area to be covered, development plans and technical and financial capability of applicants for exploration licenses and mining leases have been made in Part 7 of this report. Consideration has been given to developing regulatory procedures which will ensure the maximum and most sound, both economically and environmentally, mode of utilization of publicly owned peatlands.

B. RECOMMENDATIONS

PEAT RESOURCES

1. Given the indication of magnitude and distribution of the peat resources of Ontario and its potential for development, it is clear that a resource survey and inventory is a necessary requisite to ensure that an orderly and planned approach is taken in the development of a Provincial peat industry.

2. Whether the Province carries out a peatland inventory to the same level of detail as has been carried out in New Brunswick (a much smaller province) or starts first with an airphoto interpretation survey for the entire Province (similar to work being carried out by Monenco for the State of New York), can be considered by the Ministry in view of budget and time constraints.

MINING

1. Further to selecting a mining system for consideration for a particular region of the Province, more investigations will be required on local climate and should involve the Atmospheric Division of Environment Canada to examine the various climatic parameters and their frequency of occurrence for the areas considered.

2. Lightweight and mobile peat mining equipment is preferred for new peat operations. Both Finnish and Canadian made mining equipment is well suited to Ontario conditions and offer flexibility such as the quick-change tractor accessories. It is expected local Ontario farm tractor manufacturers can easily implement the modifications necessary for production of e.g. a peatland tractor, suitable for Ontario fuel peat mining conditions and it is recommended that this possibility be further examined.

3. It is recommended more study be given to wet mining and dewatering technology which has the attractiveness of prolonging the production season and low mining costs. The Canada Department of Energy, Mines and Resources has expressed interest in carrying out such work to complement previous peat resource, mining and thermal plant investigations and current work underway on peat processing technology.

PEAT PROCESSES

1. Considering the potential savings of petroleum-based fuels which could be realized if the JP-Energy process and product live up to expectations, it is recommended that the demonstration of this technology be followed with close attention, the market and applications of the product be investigated in greater detail and wet mining methods and costs for a site-specific Ontario application be worked out in the next phase of this study.

2. The price of natural gas in Ontario is following an upward trend and since both large scale milled peat mining technology and the PEATGAS process are in a state of rapid development, it is recommended that the feasibility of large scale SNG production via the PEATGAS technology be evaluated at a selected site in Ontario.

3. Considering methanol's rapidly increasing potential as an automotive fuel, the developing state of peat-to-methanol technology, as well as improvements in large scale milled peat mining technology, it is recommended that, in the next phase of study, the following process routes be evaluated with conditions specific for an Ontario location:

- Koppers-Totzek gasification;
- PEATGAS process, in the synthesis gas configuration;
- Studsvik MINO gasification process;

all of them coupled with a conventional methanol synthesis plant.

4. Furthermore, it is also recommended that the process and market economics of peat carbonization products be studied in greater detail than was possible within the terms of reference of this project.

POTENTIAL APPLICATIONS

1. As noted previously the potential applications identified in this report as competitive were selected by necessity on the basis of limited information. There are two general activities that can be undertaken to support the development of the applications which are related to improving the data base. The first is to conduct field investigations that would generate more detailed, possibly site specific data on potential consumption, peat resources and production costs. The second is to undertake a program to educate the potential consumer of the products identified, and measure their response to the information presented.

2. In the case of further examining the potential for "Horticultural Peat Production for Agricultural Uses" there are activities the Province could undertake to increase the likelihood of the suggested operation being established. The first activity consists of carrying out a detailed evaulation of potential horticultural peat bogs in the Province to provide potential investors with a better idea of the areas where detailed site investigations should be carried out. The second would be to assist the potential mine developer to procure capital by guaranteeing the loans made to the developer in the case of a poor production year due to bad weather.

3. To encourage the possible use of "Small Scale Sod Peat Production for Space Heating", or, "Sod Peat Production for Residential and Non-Residential Space Heating" the Province could carry out a program of educating the potential consumer and by assisting, possibly financially, in the establishment of one or more demonstration project(s) in the province (similar considerations are being studied by the Saskatchewan Government).

4. To support possible uses of peat such as "Sod Peat Production for Industrial Process Heat Generation" and "Sod/Milled Peat Production for Use in District Heating" it is recommended the Province undertake site-specific studies including cost comparisons if such investigations are not forthcoming from the potential users.

5. To assist in the development of the application "Sod Peat Production for Power Generation using a Small Scale Peat Gasifier", the Province could investigate the demand that can be expected if general purpose electrical rates are lowered in the potential markets identified and monitor the gasifier technology, especially with reference to the potential for the existing diesel generators to be converted to peat gas firing, reducing the cost of power produced.

ENVIRONMENTAL

1. From the overall environmental point of view the idea of a peatland survey and inventory is supported in order to develop more information on the peat and peatland types of Ontario, including background measurements of key environmental parameters and to further identify and quantify the deposits and rank them according to potential end use. The ranking could include items such as environmental sensitivity, wildlife and conservation uses, agriculture, forestry, recreation as well as peat mining.

2. Any demonstration project carried out to illustrate peat mining and processing techniques should be subject to monitoring of environmental effects.

REGULATORY ASPECTS

This aspect of peatland development needs to be studied in a level of detail which was beyond the scope of the current work to ensure no serious impact on the environment is caused and that the people of Ontario obtain proper benefits from the use of their resources. Existing regulations in Europe and North America should be reviewed and a listing of environmental effects and possible remedies and mitigative measures should be considered. This work is perhaps best handled within the Ministry with outside technical assistance as required.

PART 1
Introduction

Peat can be described, in very brief terms, as partially fossilized plant matter which occurs in wet areas where there is a lack of oxygen and hence the accumulation of the plant matter is more rapid than its decomposition. Peatlands are widespread throughout the world and deposits of peat vary in thickness usually from a few metres to tens of metres. Peat deposits represent a first stage in the coalification process. Peatlands are also widespread in Ontario and it is expected peat can provide a significant contribution in terms of energy, particularly in certain parts of the Province.

Peat is utilized extensively in other countries, most notably in the U.S.S.R., Ireland, Finland, China and the U.S.A. In North America, peat has yet to be produced for fuel purposes on a continuous commercial basis although a large horticultural industry exists. The U.S.S.R. is the largest peat producer in the world and peat has been used there for more than 60 years. Current annual production of fuel peat is about 100 million tonnes as well as a similar tonnage of horticultural peat. Fuel peat is consumed in about 80 electrical and thermal power stations and in briquet plants. Approximately 2% of the total energy requirement of the U.S.S.R. comes from peat.*

About 5 million tonnes of fuel peat are produced annually in Ireland and most is used in six power plants providing about 25% of the country's electrical requirement. In Finland, peat production is on the increase and although only about 2% of the country's energy requirements are currently met from fuel peat, this is expected to increase to 5-7% during the 1980's. Sweden currently produces horticultural peat and aims to become a significant fuel peat producer in the near future. In Germany, peat for energy production has declined in recent years due to dwindling resources. Peat produced is generally for horticultural purposes. Significant peat production occurs in China, about 725,000 tonnes of fuel peat and about 1.3 million tonnes of horticultural peat per year.

With escalating energy prices, attention has been turned in recent years to alternative fuels. Peat is an obvious contender in Ontario, a Province which has little significant conventional hydro-carbon resources but is known to have vast peatland areas, largely unmeasured (see Plate 1).

In the Government's September, 1979 paper *"Energy Security for the Eighties: A Policy for Ontario"*, and modified in the October 10, 1980 *"Energy Initiatives for Ontario"*, a goal to increase Ontario's capacity for energy self-sufficiency was set. A major goal for the Province is for Ontario to supply 37.5 percent of its own primary energy needs from indigenous sources by 1995.

Peat is a major northern natural resource and has been identified as a potential contributor to this goal. The development and use of peat as an energy source has not been economical to date, largely because there were cheaper, more readily available alternatives. In addition, its development has been constrained by climate conditions in harvesting or mining of it and by lack of experience and know-how in processing peat into various products.

The objective of the current work was stated in the terms of reference for the study as follows:

> "For planning the orderly development and the most efficient application of the resource, an evaluation of the various options related to prevailing conditions in northern Ontario is essential. The evaluation will assess what is currently known about peat in Ontario. It will deal with the harvesting methods applicable under northern climatic conditions, with related peat processing methods and rehabilitation techniques. It should assess the state of the processing technology and additional development work required to render a source economically feasible in relation to potential markets for its products. With respect to possible energy uses of peat, the study should assess the economics of peat as an energy resource in comparison with other fuels."

*Statistics quoted here are from the "Bulletin of the International Peat Society", February, 1981.

PART 2
Peat Resources of Ontario

2.1 INTRODUCTION

2.1.1 CANADA'S PEAT RESOURCES

The rapidly increasing interest in alternative fuels has focused interest on peat as one of a number of possible non-conventional energy sources in Canada. While in comparison with other peat producing countries Canada has potentially large resources of peat, it has become obvious that there is a definite lack of information on the actual extent of peat resources in most parts of Canada. Table 2-1 shows an estimate of peat resources in Canada based on published data available in 1972 (Simard, 1972). This information indicated only about 6 million ha of Canadian peatlands were surveyed at varying degrees of detail, none being reported for Ontario at that time. The only figure given for Ontario was about 200 ha (500 acres) under use.

More recent statistics on Canadian peat resources are shown in Table 2-2 (Tibbetts, 1980). According to this information, the potential/inferred total peatland area in Canada is over 50 million ha, almost ten times higher than the 1972 statistics on surveyed deposits. About 668,700 ha were shown to be surveyed, contrary to the earlier statistics in Table 2-1 (6 million ha). Accordinq to Table 2-2, Ontario has a total of 16 million ha of peatland of which 62,000 ha have been surveyed at varying degrees of detail. The statistics indicate that the resource data on peat in Canada is mainly based on inference, rather than on actual resource inventories.

Internationally published resource data (see Table 2-3 by Kivinen and Pakarinen, 1980), places Canada as the impressive leader with an estimated 170 million ha of peatland. Second largest in the world is the U.S.S.R. (150 million ha). Although Canada has a large part of the world peat resources (40% according to Kivinen *et al.*), it produces only about 0.2% of the total of 220 million tonnes produced (Table 2-3).

Ontario's peat resources of about 16 million ha are considerable in comparison with those of, for example, Finland (10 million ha) and Ireland (1.2 million ha). In Ireland, a total of about 5 million tonnes of fuel peat is produced from a peatland area about 13 times smaller than the area estimated for Ontario. Peat development for energy purposes in Ontario do not represent a solution to the major energy problems, however, the use of peat can help ease the general energy situation if developed in a proper manner. Before an overall peat development strategy can be put into place, it will be necessary to carry out detailed surveys of Ontario's peat deposits to accurately establish their location, potential for commercial development, and their suitability to be altered from their natural state. The most recent figures indicate that only 62,000 ha have been surveyed in Ontario (Table 2-2). This is only about 0.4% of the total estimated Ontario peatland area.

TABLE 2-1. DISTRIBUTION OF PEATLAND IN CANADA (SIMARD, 1972).

Province	Surveyed Area		Exploitable Area		Exploited	
	Acres	ha	Acres	ha	Acres	ha
British Columbia	2,385,000	965,000	47,000	19,000	2,000	800
Alberta	2,000,000	809,000	—	—	400	160
Saskatchewan	10,000,000	4,048,500	—	—	2,000	800
Manitoba	92,500	37,450	4,900	1,980	1,000	400
Ontario	—	—	—	—	500	200
Quebec	255,000	103,200	59,000	24,000	7,000	2,800
New Brunswick	—	—	—	—	6,000	2,400
Nova Scotia	9,000	3,650	5,000	2,000	400	160
Prince Edward Island	6,400	2,600	1,000	400	100	40
Newfoundland	28,500	11,500	5,000	2,000	5	2
Total	14,776,400	5,981,400	121,900	49,380	19,405	7,762

TABLE 2-2. PEAT RESOURCES OF CANADA (TIBBETTS, 1980).

Province	Potential/Inferred Peat Resources		Measured Peat Resources		% of Total Peatland Area
	Hectares	Tonnes* x 10^6	Hectares	Tonnes x 10^6	
Newfoundland	2,000,000	3,400	360,000	612	18.0
Nova Scotia	10,000	45	5,100	23	50.0
P.E.I.	2,000	2	2,000	2	100.0
New Brunswick	100,000	170	60,000	103	60.0
Quebec	12,000,000	20,680	50,000	64	0.4
Ontario	16,000,000	27,580	62,000	135	0.4
Manitoba	5,500,000	9,525	106,000	103	2.9
Saskatchewan	4,000,000	6,890	16,000	27	0.4
Alberta	10,000,000	17,240	1,600	3	0.2
British Columbia	970,000	1,630	6,000	20	0.6
NWT and Yukon		- NOT AVAILABLE -			
Total	50,582,000	87,162	668,700	1,092	1.3

* At 50% Moisture

TABLE 2-3. WORLD PEAT RESOURCES (KIVINEN AND PAKARINEN, 1980).

Country	Biological Peatland ha x 10^6	Peat Production - Tonnes x 10^3		
		Fuel Peat	Moss Peat	Total
Canada	170.0	—	488	488
U.S.S.R.	150.0	80,000	120,000	200,000
U.S.A.	40.0	—	800	800
Indonesia	26.0	—	—	—
Finland	10.0	3,100	500	3,600
Sweden	7.0	—	270	270
China	3.5	800	1,300	2,100
Norway	3.0	1	83	84
Malaysia	2.4	—	—	—
United Kingdom	1.6	50	500	550
Poland	1.4	—	280	280
Ireland	1.2	5,570	380	5,950
West Germany	1.1	250	2,000	2,250
Total	417.2	89,771	126,601	216,372
Total (Approx.)	420.0	90,000	130,000	220,000

2.1.2 PRESENT INFORMATION ON ONTARIO PEATLANDS

This study represents a first attempt to produce a more accurate picture of the distribution and quantity of peat and peatland in the Province. While the basic information is still inferred, the final maps and calculations give a more accurate picture of the peat resources of Ontario than previously was available. This present work can be used as a basis on which to design a detailed peatland inventory program and as well to plan the preliminary development of a peat industry in the Province.

No fieldwork has been involved and all the information has been gleaned from the available published sources. The information used can be divided into two main categories: 1) publications in journals and reports, and 2) maps (with some reference to aerial photographs).

Although the literature published on peat, with references to Ontario peatlands, is quite extensive, most references relate to various scientific applications with little or no resource quantity or peat type information. This is to be expected, in view of the earlier comments on the existing statistics on Ontario peat resources. The published literature spans a number of years with some of the earliest works being published by Anrep (1908-14) on *"Peat Bogs and Industry of Canada"* and as well by Haanel on *"Peat, Lignite and Coal"* (1914), *"Facts about Peat"* (1924), and *"Final Report of the Peat Committee"* (1925), and a number of other peat investigations in Ontario and Quebec by Anrep (1919, 1920 and 1921).

Relatively extensive peat surveys were carried out by Auer in eastern Canada during the 1920's, (Auer 1927, 1928 and 1930). In his investigations, Auer covered a number of peatlands from the Maritimes to Ontario. Detailed peat profiles were produced showing the thickness of peat and peat types for a number of Ontario peatlands in addition to some paleontological work.

More recent peat investigations on Ontario peat have been carried out by Leverin in 1942 and 1946 including a number of analyses on peat as well as the extent and the thickness of deposits studied. The most recent reports on peat surveys in the Province are by Graham and Tibbetts (1961 and 1965) and by Graham for the Ontario Geological Survey (Graham, 1979). The studies by Graham cover some 54 individual peat deposits from southern to western Ontario. They give a thorough description of the deposits including aspects such as peat quality, quantity, bog accessibility, location, topography, drainage, area, type and thickness of the deposit. The work by Graham includes information from across the Province and is most comprehensive and hence has been a main source of basic information for the peat resource calculations, including derivation of the estimates of the proportions of fuel to moss peat.

Other publications having research aspects related directly or indirectly to peatland and peat are numerous. These include studies on forestry, hydrology, vegetation, classification and mapping such as those by Ketcheson and Jeglum (1972), Sjörs (1963), Dai (1971), Boissonneau and Jeglum (1976), Jeglum *et al.* (1974), Stanek *et al.* (1977), Dai *et al.* (1974), Kalela (1962), and Zoltai *et al.* (1974). These are a few examples of the variety of literature dealing with peat and peatland in Ontario. A more comprehensive listing of articles used in this report is given in the list of references.

In addition to the works dealing directly with peat and peatland, there are others indirectly associated with peatland as a type of wetland. Personnel at the Ontario Centre for Remote Sensing have been carrying out a number of remote sensing projects dealing with the interpretations of various landforms, using the most modern remote sensing techniques. A basic aim of the work has been also to classify wetlands, particularly in the Hudson Bay Lowlands area (Pala, 1979, Boissonneau and Pala, 1978). While a large number of ground checks have been carried out on the Hudson Bay peatlands, no information is yet available on the details, pending the final outcome of the work.*

The existing mapping with information on wetlands in Ontario is very limited and generalized. Apart from maps of individual peatlands, a comprehensive system of maps covering peatlands as a discrete mapping unit does not exist. The most comprehensive aids in this respect were the topographical maps of the national topographic series, at the scale of 1:50,000 and 1:250,000. The entire Province is covered at the latter scale while the former provides coverage for only parts of the Province. On these maps, the wetlands have been outlined to a relative degree of accuracy. However, peatland either in its biological or geological sense is not included as a separate map unit, and thus the areas marked as wet may contain wetlands other than peatland, causing some loss of accuracy when the topographic maps are used.

The Ontario Ministry of Natural Resources is carrying out a mapping project from engineering geology terrain studies. Approximately 58 maps of the series at 1:100,000 scale were available at the time of the present study. The maps have organic terrain as a mapping unit and were used to supplement the information obtained from the topographic maps.

2.2. PEAT AND PEATLAND CLASSIFICATION

2.2.1 PEAT CLASSIFICATION

2.2.1.1 SYSTEMS USED

What is peat? Even this has not been agreed upon universally. In this study, peat is considered to be organic material with a maximum of 40% ash (mineral matter) content. When encountered in the field, the minimum thickness of this material is to be 0.3 m, for consideration as a peat deposit in a geological sense.

There are a number of systems for peat classification in use. However, recently some standardization has been achieved mainly through efforts made by the International Peat Society and by the American Society for Testing and Materials (ASTM) who are actively engaged in peat standardization. It is expected that a number of systems will be used to obtain an internationally acceptable system suitable for various end uses.

The most common peat classification systems proposed in Canada and the U.S.A. are those by Radforth (1952), Day (1968), and Farnham (1968). The Radforth system has not gained wide use, mainly because of the lack of reference to the original botanical constituents of peat and to the degree of humification. The system is entirely based on a combination of morphological constituents such as granular or amorphours material held in a fibrous, non-fibrous, woody or non-woody framework. This system does not lend itself to an easy reference to ecological or energy properties of peat and is only used for limited engineering assessments of peats.

The system described by Day (1968) has been adopted by the National Soil Survey Committee of Canada. In this system, the deposit is divided into tiers (surface, middle, and bottom) each of which may have one or more kinds of layers—diagnostic layers (fibric, mesic, humic) and other layers (e.g. typic, fenno, terris, etc.). Thus, peat types can be described as fenno-fibrisol, humic-mesisol, etc. While this system has gained acceptance among soil scientists, it has not been adopted by the International Peat Society.

*Oral communication, Pala (1981)

The reasons are varied. Some included the omission of a clear indication of the original botanical constituent of the peat, the degree of humification and graded indication of fibrocity and moisture content.

TABLE 2-4. VON POST DEGREEE OF HUMIFICATION.

Degree of Humification — von Post's Scale	Description
H1	Completely undecomposed peat which, when squeezed, releases almost clear water. Plant remains easily identifiable. No amorphous material present.
H2	Almost completely undecomposed peat which, when squeezed, releases clear or yellowish water. Plant remains still easily identifiable. No amorphous material present.
H3	Very slightly decomposed peat which, when squeezed, releases muddy brown water, but for which no peat passes between the fingers. Plant remains still identifiable, and no amorphous material present.
H4	Slightly decomposed peat which, when squeezed, releases very muddy dark water. No peat is passed between the fingers but the plant remains slightly pasty and has lost some of the identifiable features.
H5	Moderately decomposed peat which, when squeezed, releases very "muddy" water with also a very small amount of amorphous granular peat escaping between the fingers. The structure of plant remains is quite indistinct, although it is still possible to recognize certain features. The residue is strongly pasty.
H6	Moderately strongly decomposed peat with a very indistinct plant structure. When squeezed, about one-third of the peat escapes between the fingers. The residue is strongly pasty but shows the plant structure more distinctly than before squeezing.
H7	Strongly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed, about one-half of the peat escapes between the fingers. The water, if any is released, is very dark and almost pasty.
H8	Very strongly decomposed peat with a large quantity of amorphous material and very dry indistinct plant structure. When squeezed, about two-thirds of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibres that resist decomposition.
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed, almost all of the peat escapes between the fingers as a fairly uniform paste.
H10	Completely decomposed peat with no discernible plant structure. When squeezed, all the wet peat escapes between the fingers.

The system described by Farnham (1968), not commonly used in Canada, has gained quite wide acceptance in the U.S.A. This system was proposed by the ASTM. It is mainly based on the division of peats by botanical (generic) origin and fibre content, whereby 4 different major peat types are established (sphagnum moss peat, other moss peats, humus peat, reed-sedge peat). This system closely follows other systems used for horticultural peat classification in Europe. However, due to the emphasis on the horticultural use of peat, this system *per se*, has not gained wide acceptance for other purposes outside the U.S.A.

The International Peat Society and ASTM are working towards a comprehensive classification system for peats. In the meantime, the modified von Post method has perhaps been the most widely used and is proposed for Ontario peat surveys. This system is the most comprehensive and a person with a solid background in peatland studies can interpret it for engineering, ecological, commercial and other applied purposes. It has been widely used all over Europe, extensively in Canada (e.g. New Brunswick peat inventory) and also in the U.S.A. (Korpijaakko, E., and Woolnough, D., 1975).

2.2.1.2 MODIFIED VON POST SYSTEM

Peat is usually a combination of remains of a number of plant groups, rather than a single group. According to the von Post system, the peat type is classified by utilizing the recognizable features of the orginal plant constituents which formed the peat. The most common plants forming peat and the symbols used for them in the peat formula (see below) are: *Sphagnum* (S), *Carex* (C), *Eriophorum* (ER), *Equisetum* (EQ), *Phragmites* (PH), *Scheuchzeria* (SCH), shrubs (N = nanolignidi), wood (L = lignidi), and mosses (other than sphagnum, i.e. Bryales). In some cases it is desirable, if possible, to specify the composition more accurately by direct reference to the species composition (e.g. *Sphagnum fuscum* peat). Any other plant material recognizable as a significant contributor in the peat deposit under investigation should be recorded also.

It has been customary in some European countries to mention the less significant constituents first, as is done in soil classification systems generally. According to this principle, a peat composed mainly of *Carex* but with smaller amounts of *Sphagnum* would be called: Sphagnum - Carex peat (SC peat).

The degree of humification, which is indicated by the letter 'H', is divided into 10 categories as shown in Table 2-4. Table 2-5 includes additional elements of the peat formula including moisture regime, fibre content and degree of woodiness. The fine fibre content is estimated and expressed by utilizing a scale of 0-3 and the symbol 'F'. The fibres are, in this case, mainly derived from *Eriophorum*. If any other fine fibres are recorded they should be identified as in the peat formula. The coarse fibres are also estimated by using a scale of 0-3 and the symbol 'R' is used in the manner tabulated above. In this case, mainly rootlets are recorded. Often the rootlets of *Carex* are referred to and also identified in the formula as such. The presence of woody remnants in the peat can present mining problems, especially when considering the peat for moss peat production. For this purpose a scale of 0-3 and the symbol 'W' are used to describe the degree of woodiness.

TABLE 2-5. VON POST MOISTURE REGIME, FIBRE CONTENT, AND DEGREE OF WOODINESS.

Moisture Regime 'B' (Scale 1 to 5)	Fine Fibre Content 'F' (Scale 0 to 3)	Coarse Fibre Content 'R' (Scale 0 to 3)	Woodiness 'W' (Scale 0 to 3)
B_1 Dry Peat	F_0 Nil	R_0 Nil	W_0 Nil
B_2 Low moisture content	F_1 Low content	R_1 Low content	W_1 Low content
B_3 Moderate moisture content	F_2 Moderate content	R_2 Moderate content	W_2 Moderate content
B_4 High moisture content	F_3 High content	R_3 High content	W_3 High content
B_5 Very high moisture content			

TABLE 2-6. SUMMARY OF PROPERTIES DESIGNATING NINE PURE COVERAGE CLASSES (FROM RADFORTH, 1952).

Coverage Type (Class)	Woodiness vs. Non-woodiness	Stature (approx. height)	Texture (Where required)	Growth Habit	Example
A	woody	15 ft or over	—	tree form	Spruce, Larch
B	woody	5 to 15 ft	—	young or dwarfed tree or bush	Spruce, Larch Willow, Birch
C	non-woody	2 to 5 ft	—	tall grass-like	grasses
D	woody	2 to 5 ft	—	tall shrub or very dwarfed tree	Willow, Birch Labrador tea
E	woody	0 to 2 ft	—	low shrub	Blueberry Laurel
F	non-woody	0 to 2 ft	—	mats, clumps or patches sometimes touching	Sedges Grasses
G	non-woody	0 to 2 ft	—	singly or loose association	Orchid, Pitcher Plant
H	non-woody	0 to 4 in	leathery to crisp	mostly continuous mats	Lichens
I	non-woody	0 to 4 in	soft or velvety	often continuous mats sometimes in hummocks	Mosses

The Radforth cover classification system (distinct from the Radforth peat classification system or is a portion thereof) is widely used both in North America and Europe to give information on the basic botanical structure of the peatland surface cover to aid the user to determine, for example, trafficability of the bog as well as problems that might be encountered in preparing it for production. Table 2-6 describes this system. The Radforth cover classes have been added to the von Post system to extend the peat and peatland description as described in the peat formula. The term "modified" von Post system refers to the fact that the original von Post system consisted of only the degree of humification assessment while the modern use includes all the above described aspects (fibre, etc.).

Other information, when pertinent, is added to the end of the formula using suitable symbols and abbreviations. Thus, layers of charcoal indicating old fires, seeds, and other recognizable plants remnants may be noted. In the whole sample site, the last items to be recorded are the possible layers of detritus ooze, gyttja, and finally the type of bottom soil.

During the course of carrying out peatland surveys the various information is recorded on data sheets for each sampling location. The peat formula determined for a particular sampling site might look something like the following:

Site BL 10 (= Site No. 10 on the Baseline)
Cover FI (Radforth system, see Table 2-6)
0-30 $SCH^{1-2}B^3F^0R^2W^0$ (seeds = *Potentilla palustris*)

The above indicates that from the surface to a depth of 30 cm the peat is composed of *Sphagnum-Carex* remnants, the decomposition varies from nil to very slight, the quantity of moisture is moderate, the quantity of fine fibres is nil and that of coarse fibres moderate, no woody material is present, and *Potentilla palustris* seeds were identified.

The modified von Post or other peat classification system does not give information on the physical or chemical properties of peat. This information is obtained in each individual case by analysing samples of peat. While the analytical results vary from site to site, they usually fall within broad limits for various peat types and degrees of humification. Thus, the basic peat classification, together with the results of laboratory analyses, can form a data base on which to establish a second set of classification criteria for the purposes of the end-user. It may be argued that this secondary system is not really a classification system but rather a set of potential product descriptions.

For practical purposes, a very simplified classification of peat used for horticultural or energy purposes can be made by using degree of humification and peat type. Peat can be subdivided into slightly humified and highly humified groups without regard to peat type, although peat type determines where the division between slightly and highly humified is made. Peat types can be divided into sphagnum peats and others non-sphagnum peats. Sphagnum peats are those containing 50% or more of sphagnum residues. The "others" contain components, such as sedges, in predominance. The others, for the sake of simplification, can be called sedge peats and would cover such types as reed-sedge, peat humus, woody peats, and Hypnum peats.

Slightly humified peats (H1-4 for sphagnum and H1-3 for sedge peats) are commonly referred to as non-energy peats. Energy or fuel peats have a higher degree of humification (H5 or more and H4 or more for sphagnum and sedge peats, respectively). For instance, one can refer to a highly humified sedge peat as a fuel peat. This simplified classification of peat has been found to be useful for discussion purposes.

2.2.2 PEATLAND CLASSIFICATION

The term peatland may be used to refer to various types of landforms depending on the user's basic background. Also, there are several terms which from time to time and place to place have been alternatively used to refer to peatland in general, or to certain types of peatland in particular. All this reflects the same non-standardization use of terminology as is encountered with the term peat. The International Peat Society and the ASTM are also engaged in the development of a standardized system(s) for peatland classification. While the final system(s) has not been decided upon, certain basic descriptions of terms is given below.

A peatland can be classified in two senses: biologically and geologically. Biologically, a peatland is a landform usually having a high water table, covered by vegetation typical to waterlogged conditions and recognizable as such. If favourable conditions prevail (high water table, and usually a cool climate), accumulations of peat results. A biological peatland may or may not contain peat depending on its age, that is, in young peatlands, not enough time may have elapsed for the accumulation of peat to have occured.

Geologically, a peatland is any landform containing an overburden of peat of a specified minimum thickness. There is widespread disagreement about the minimum thickness. For the peat mining industry it is often set at one metre to be considered mineable, while geologists usually set it at 30 cm. However, recent developments in peat mining equipment allow peat mining on shallow deposits which have as little as 30 cm of peat. Hence, in this study, it is suggested that the 30 cm minimum thickness be adopted when referring to a peatland in the geological sense.

As this work deals with the basic aspects of peatlands, a comprehensive description of peatland classification is not warranted. Brief reference to the main types will be given to reveal the complexity of peatland classification to the reader.

2.2.2.1 BASIC PEATLAND CLASSIFICATION

One of the oldest ways of dividing peatlands is to group them into two main types: ombrogenic and minerogenic peatlands (e.g. Ruuhijarvi, 1960). The division is also an indication of the basic climatic conditions at the site of occurrence. Ombrogenic peatlands occur in areas of a higher surplus of water, as they depend on the atmospheric water. A high surplus of water is caused by a combination of ratios between evapotranspiration rates, precipitation and impervious soils. Peatlands formed in conditions like this are usually raised and dome-shaped and often are also called raised bogs. They show a typical pattern or more or less concentrically arranged arched ridges and rimpis (flashets). The ridges are at 90° angles to the flow of water. If the center, around which the ridges are arranged, is in the middle of the bog, the bog is called concentric and when the center is near the edge of the bog it is called eccentric. Plates 2-11 and 2-12 give a generalized line drawing of the basic peatland types.

A raised or ombrogenic bog is also ombrotrophic or oligotrophic (low in nutrient) because most of its nutrients come from atmospheric water. The peat in these bogs is predominantly sphagnum peat. This is because sphagna are oligotrophic and also can retain large quantities of water due to their special cellular structure. The high water level and fast growth ensures a low degree of humification of peat. Thus, thick layers of sphagnum peat accumulate. Conditions for ombrogenic peatlands are most favourable in the cool humid coastal climates, as the widespread bogs in the eastern and western Canadian regions testify. This type of peat is best suited for horticultural uses. Quite commonly the term "bog" in literature is used loosely to refer to ombrogenic, raised peatland.

Minerogenic peatlands are located in areas where the ground becomes waterlogged. This is not always so much because of the presence of a surplus of water but for other reasons such as impervious soil and a depression with blocked water flow. The minerogenic peatlands are usually more featureless without ridges and rimpis, except in more northerly areas where string bogs abound. The strings are not concentric.

The peat layers in minerogenic peatlands are slightly less thick than in the ombrogenic ones. They also contain more sedges, wood and more eutrophic plant species than sphagna. The nutrient content is medium to high (mesotrophic to eutrophic), and pH is closer to neutral (4.0-6.5) than in ombrogenic (3.0-4.5) peatlands. Due to the slower growth rate and higher aeration, the peat is usually well humified (H5-10 vs. ombrogenic H2-5) and better suited for in situ agriculture, forestry or for mining for energy purposes. Minerotrophic peatlands are found in larger quantities in the continental climatic regions. However, both types can be found interlaced depending on the climatic and local drainage conditions. Often minerogenic peatlands are called by the name "fen".

The division of peatlands into classification series ombrogenic-minerogenic gives us a continuum in which there is a gradual change from one to another. This change (oligotrophy-mesotrophy-eutrophy) is reflected in the vegetation covering the peatlands. The vegetation is composed of plant species demanding certain kinds of climatic and nutrient level. The surface vegetation also reflects peat type underneath to varying depths, depending on the recent geological history of the region. Based on these principles, and especially on the knowledge of the limits of trophic level which the plants require, they can be grouped into a series varying from oligotrophic through mesotrophic to eutrophic, and those which are indifferent. The latter means plants tolerant to varying nutrient levels.

Thus, surface vegetation is the reflection of the present ecological condition of the peatland. By standard phytosociological analysis (Braun-Blanquet, 1932) peatlands can be divided into a number of classes indicating the ecological conditions prevailing at the site. Knowledge of the local recent (10,000 to 12,000 years) palaeoclimatic history gives an approximate indication of possible peat types expected to be encountered in a deposit. The ecological classification systems are usually quite complex and may be composed of up to 80 classes (Ruuhijarvi, 1960). Usually for any practical work only up to 28 are used. This system has been further simplified for forestry use.

A basic peatland classification system, commonly used in Europe, was designed by Cajander (1913) mainly for forest ecological purposes. He divided peatlands into open and closed or treed peatlands. Each were divided into two categories: eutrophic and oligotrophic types. The system has been modified slightly to fit the Canadian conditions and has been applied to peatland classification in Canada by Heikurainen (1968). Based on this system and a number of other works, system towards a wetland classification for Ontario was proposed by Jeglum *et al.* (1974) and can be considered a basis on which to base future, more detailed work on peatland classification for Ontario.

2.2.2.2 PEATLAND DIVISION AND CLASSIFICATION USED FOR ONTARIO

It is difficult to design a simple division of Ontario into regions where certain peatland types predominate. A number of divisions, depending on the bias of the researcher, have been used. The most common are those based on the Rowe's (1972) forest regions and Ahti's (1964) broad vegetation regions. The work by Jeglum *et al.* (1974) follow these to a certain extent as far as regional grouping is concerned. However, when one considers the underlying peat, the palaeoclimatic and palaeoecological aspects also enter into the picture and consequently, the existing surface classification may not bear any relation to the underlying peat types. For this reason the present work has used a simplified physiographic division of Ontario as a basis of a possible future peatland classification division as discussed in Section 2.3.4 of this report (see Plate 2-4). For the surface use, agriculture and forestry and related fields, the regionalism may be also based on the Rowe's or Ahti's divisions.

As far as peatland types are concerned, they are classified by Jeglum *et al.* into bogs, fens, marshes and swamps. These have a close relationship to the original Cajander's system. The following are the peatland descriptions that have been used and described by Zoltai *et al.* (1974):

BOG "Bogs are peat-covered areas of peat-filled depressions with a high water table and a surface carpet of mosses, chiefly Sphagnum. The water table is at or near the surface in the spring, and slightly below during the remainder of the year. The mosses often form raised hummocks, separated by low, wet interstices. The bog surface is often raised, or if flat, level with the surrounding wetlands, it is virtually isolated from mineral soil waters. Hence, the surface bog waters and peat are strongly acid and the upper peat layers are extremely deficient in mineral nutrients. Peat is usually found *in situ* (autochthonous peat) under closed drainage, and oxygen saturation is very low. Although bogs are usually covered with *Sphagnum*, sedges may grow on them. They may be treed or treeless, and they are frequently characterized by a layer of Ericaceous shrubs."

Two subformations of BOG recognized by Zoltai are OPEN BOG and TREED BOG. OPEN BOG has typical BOG characteristics with less than 10% canopy cover by trees comprised primarily of black spruce, which are at least 135 cm high. TREED BOG has typical BOG characteristics with more than 10% canopy cover by trees which are at least 135 cm high.

FEN "Fens are peatlands characterized by surface layers of poorly to moderately decomposed peat, often with well decomposed peat near the base. They are covered by a dominant component of sedges although grasses and reeds may be associated in local pools. *Sphagnum* is usually subordinate or absent, with the more exacting mosses being common. Often there is much low to medium height shrub cover and sometimes a sparse layer of trees. The waters and peats are less acid than in bogs of the same area, and sometimes show somewhat alkaline reactions. Fens usually develop in restricted drainage situations where oxygen saturation is relatively low and mineral supply is restricted. Usually very slow internal drainage occurs through seepage down very low gradient slopes, although sheet surface flow may occur during spring melt or periods of heavy precipitation."

The subformations of FEN recognized by Zoltai are OPEN FEN and TREED FEN. OPEN FEN has typical FEN characteristics with less than 10% canopy cover by trees, primarily tamarack, that are at least 135 cm high. TREED FEN has typical FEN characteristics with more than 10% canopy cover by trees that are at least 135 cm high.

MARSH "Marshes are grassy wet areas, periodically inundated up to a depth of 2 meters or less with standing or slowly moving water. Surface water levels may fluctuate seasonally, with declining levels exposing drawndown zones of matted vegetation or mud flats. Marshes are subject to a gravitational water table but water remains within the rooting zone of plants at least part of the growing season. The substratum usually consists of mineral or organic soils with a high mineral content, but there is little peat accumulation. Waters are usually circumneutral to alkaline, and there is a relatively high oxygen saturation. Marshes characteristically show zonal or mosaic surface patterns of vegetation, comprised of unconsolidated grass and sedge sods, frequently interspersed with channels or pools of open water. Marshes may be bordered by peripheral bands of trees and shrubs, but the predominant vegetation consists of a variety of emergent nonwoody plants such as rushes, reeds, reedgrasses and sedges. Where open water areas occur, a variety of submerged and floating aquatic plants flourish."

SWAMP "Swamps are wooded wetlands where standing to gently flowing waters occur seasonally or persist for long periods on the surface. Frequently there is an abundance of pools and channels indicating subsurface water flow. The substrata is usually continually waterlogged. Waters are circumneutral to moderately acid in reaction, and show little deficiency in oxygen or in mineral nutrients. The substrata consists of mixtures of transported mineral and organic sediments, or peat deposited *in situ*. The vegetation cover may consist of coniferous or deciduous trees, tall shrubs, herbs and mosses. In some regions *Sphagnum* may be abundant."

Of these types the "bogs" are at the oligotrophic end of the trophic system while "fens" are at the eutrophic end. While ombrogenic peatlands are not common or well developed in Ontario, they still occur whenever the conditions are favourable. Ombrogenic peatland would be included in the "bog" types and depending on their stage of development may show various degrees of tree cover. Marshes and swamps are usually eutrophic with no peat or very shallow peat.

2.3 BASIC CHARACTERISTICS OF PEAT AND PEATLAND IN RELATION TO THEIR USE

2.3.1 GENERAL PHYSICAL AND CHEMICAL CHARACTERISTICS OF PEAT

Peat is composed mainly of organic matter with the organic content varying from a low of 20% (when classified under organic soils for geotechnical purposes) to as high as over 99% for very pure peats.

Tables 2-7, 2-8 and 2-9 give examples of the basic chemical composition of peat. These values have been measured for a large number of samples of various peat types and give average limits for the wide variety of peats as they have been analysed in Sweden (Assarsson, 1961), Finland, Germany and Canada. The values are within the limits of Canadian peats in general, and the basic values are applicable to Ontario conditions.

Table 2-7 is an indication of the basic breakdown of some plant cellulose and hemicellulose and related matter to humic acids. As the content of cellulose matter decreases from 15-20% to nil and the humic acid content increases from 0-5 to 50-60% and colloidal matter and gases increase, the degree of humification increases. During this process, some of the material is lost as gases. However, various other substances increase in proportion to others and increase the value of the peat as a source of fuel since the calorific value and the bulk density increase.

TABLE 2-7*. AVERAGE PERCENTAGES OF VARIOUS ORGANIC MATTER IN PEATS OF VARYING DEGREE OF HUMIFICATION.

	H1-2 % Dry Matter	H5-6 % Dry Matter	H9-10 % Dry Matter
Cellulose	15-20	5-15	—
Hemicellulose	15-30	10-25	0-1
Lignin	5-40	5-30	5-20
Humic acids	0-5	20-30	50-60
Bitumen	1-10	5-15	5-20
Nitrogen compounds (similar to protein)	3-14	5-20	5-25

*According to Assarsson, 1961

TABLE 2-8. ELEMENTAL COMPOSITION OF THE ORGANIC MATTER IN PEAT.

	C%	H%	O%	N%	S%
H1-2	48-53	5.0-6.1	40-46	0.5-1.0	0.1-0.2
H5-6	56-58	5.5-6.1	34.39	0.8-1.1	0.1-0.3
H9-10	59-63	5.5-7.0	31.34	0.9-1.9	0.2-0.5

Table 2-8 is an indication of the process described above showing an increase in the quantity of carbon and hydrogen as the degree of humification increases. These two elements are significant when determining the calorific value of peat.

TABLE 2-9. ASH COMPOSITION OF PEATS FROM GERMANY, FINLAND AND CANADA.

	% of Dry Ash (weight)		
Substance	**German Data (1)**	**Finnish Data (2)**	**Canadian Data (3)**
K_2O	0.1- 2.5	0.1- 0.4	0.4- 2.8
CaO	2.0-45.0	1.5- 4.6	1.3-42.7
MgO	1.0-20.0	—	4.4- 5.3
Al_2O_3	1.0-11.0	1.3- 5.1	3.3-23.1
SiO_2	10.0-45.0	50.0-72.0	7.9-38.8
Fe_2O_3	1.5- 5.5	4.6- 7.1	2.4-11.6
S	—	0.2	0.01-0.75
MgO	1.0-20.0	—	1.3-27.8
MnO	0.1- 0.3	—	0.1- 0.2
$K_2/$	0.1- 2.5	—	0.4- 2.8
$Na_2/$	0.2- 5.0	—	0.3- 2.0
P_2O_5	1.0- 3.0	2.3- 4.2	0.0- 2.6

Sources:
(1) After Naucke, 1968
(2) After Ekman, 1976
(3) Korpijaakko and Pheeney, 1975
Saskmont Engineering and Saskatchewan Mineral Resources, 1981
Tibbetts, 1976
Risi et al. 1954 and 1955

Table 2-9 gives ash composition analysis values for peat ash from Finland, Germany and also from Canada. The elements and components in this table are those commonly measured both for energy and non-energy uses as they reflect both the nutritional values for agricultural and related peat uses and slagging properties of peat ash boilers. As the table reveals, the ash comparison varies widely. The values were measured for sedge peats and reflect those for peats with a high degree of humification and possibly a relatively high ash content (the actual ash content was not given for these specific analyses). The Canadian values are for varying peat types with an ash content varying from 1% to 27% (dry weight). Table 2-10 summarizes a few characteristics of Ontario peats as available in literature.

TABLE 2-10. SUMMARY OF ONTARIO PEAT QUALITY DATA.

Calorific value (kcal/kg)	2255 - 5611
Sulphur (% of ash)	0.1 - 0.5
Ash %	0.8 - 3.0
pH	3.4 - 6.9

Source: Graham, 1979.

On the whole, the ash composition of Canadian peat is within the same wide range as European peat. Differences in ash composition may be related also to the mode of paludification, location of peatland in relation to, for example, sand dune areas (e.g. high SiO_2 content in Ekman's values), etc.

Table 2-11 is an example of a broad comparison of the main peat type composition based on the ASTM/Farnham classification. The same table also compares this system with the von Post degree of humification and the basic tiers of the U.S. Department of Agriculture soil class system.

This table reveals a great increase of pH from a low of 3.2 for slightly humified sphagnum peat up to alkaline pH 8.0 for decomposed humus. Well humified reed-sedge peat has a higher pH value of 7.5. The bulk density increases similarly from 48-80 kg/m^3 (sphagnum) to 80-96 kg/m^3 for sedge peat and 280-480 kg/m^3 for humus.

The variation in *in situ* water content is not as drastic and may be accounted for by the higher water holding capacity of sphagnum vs. sedges (90-95% wet weight for sphagnum, 80-90% for well humified reed-sedge peat).

TABLE 2-11. CLASSIFICATION OF PEATS.

Type	**Sphagnum Moss Peat (peat moss)**	**Hypnum Moss Peat**	**Reed Sedge Peat**	**Peat Humus**	**Other Peat**
Fibre, wt %[a,b]	Minimum of 66⅔ Sphagnum moss fibre	Minimum of 33⅓ total fibre, of which over 50% is Hypnum moss	Minimum of 33⅓ total fibre, of which over 50% is Reed sedge or other non-moss	Less than 33⅓ fibre	All forms not otherwise classified

Farnham

Type	Sphagnum moss Peat	Hypnum moss Peat	Reed sedge Peat	Partly decomposed (reeds, sedges, grasses)	Decomposed (humus)
pH	3.2-4.0	5.0-7.0	4.0-7.0	4.0-7.5	3.5-8.0
kg/m^3	48-80	64-96	80-96	112-192	280-480
Max. water, wt %	90-05	90-92	90-92	80-90	80-90
Av nitrogen, wt %[b]	0.7-1.2	1.5-2.5	1.0-2.5	1.2-3.0	1.5-3.5
Av fibre, wt %[b]	85-95	80-85	70-80	40-60	10-20

ASTM/Farnham[c]

→ 1,2,3 → → 4,5,6 → → 7,8,9,10 →

von Post degree of Humification

Fibric Hemic Sapric

U.S. Dept. of Agriculture Soil Class System

[a]Fibres are defined as plant material retained in an ASTM No. 100 sieve; that is, material 0.15 mm or larger, consisting of stems, leaves, or fragments of bog plants, but containing no particles larger than 0.5 inch (12.7 mm). It excludes fragments or other materials such as shells, stones, sand, and gravel. [b]Oven-dried peat, unground. [c]ASTM Designation: D2607-69 (effective April 25, 1969). American Society for Testing and materials. (After Punwani, 1980).

2.3.2 CHARACTERISTICS OF NON-ENERGY PEATS

2.3.2.1 GENERAL

The non-energy uses of peat are varied. For *in situ* agricultural and forestry uses, shallow well humified peats composed of sedge, woody peats, etc., are excellent because they form a good organic bed with a high nutrient value and relatively high cation exchange values. These properties of peat improve the poorer underlying mineral soil and enhance plant growth. Since the present work is aimed more at the extraction of peat as a marketable material, the *in situ* uses will not be discussed in detail.

The peats best suited for non-energy uses such as a growing medium for greenhouses, household, domestic and commercial gardens, landscaping, manufacture of peat pots, pellets, growing plates (instant lawn), oleophilic peat for pollution control, filtering medium (pollution control), insulating boards, to mention a few are sphagnum peats of a low degree of humification. In most cases the best are sphagnum peats with a degree of humification of H2-4, but also peat with humification values of H5-6 can be used, although certain characteristics, such as water holding capacity are considerably lower than that of H1-4.

The characteristics of slightly humified sphagnum peats which make them sought after for agricultural purposes are their high water holding capacity, high cation exchange capacity, high pore space, relatively high permeability, compressibility, and capability of resuming the original structure even after a compression ratio of 10:1. All these characteristics depend on the structure of sphagnum moss.

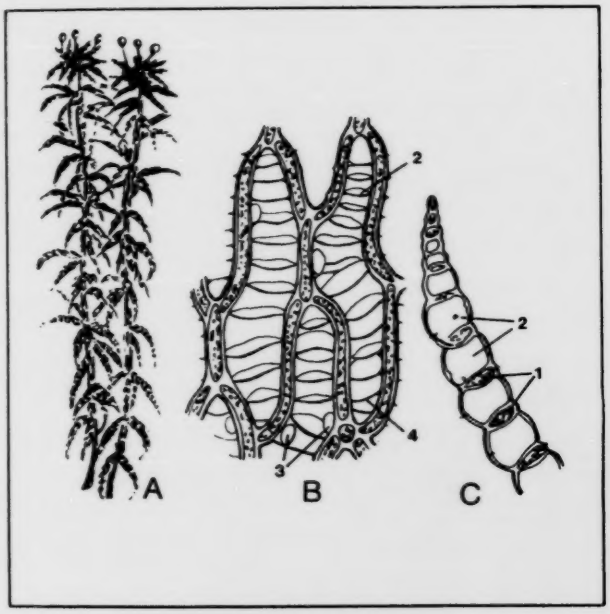


PLATE 2-1. STRUCTURE OF SPHAGNUM MOSS.

A. Sphagnum, natural size.
B. Leaf cell tissue seen from above (magnified 300 X).
C. Cross section of leaf (magnified 300 X).
1) Narrow chlorophyllic cells.
2) Hyaline cells with ring-shaped thickenings.
3) Pores.
4) Reinforcing rings.
(Puustjarvi, 1977).

2.3.2.2 PHYSICAL AND CHEMICAL STRUCTURE OF SPHAGNUM PEAT

There are about 300 species of sphagna widely spread both in the northern and southern hemisphere. They are almost ubiquitous constituents of peat, especially in locations where the surplus moisture might otherwise be able to run off. They form peat mostly either in highly waterlogged conditions or in the areas of cool humid climates, all of which are conducive to a low rate of degradation (humification) in relation to rate of accumulation.

Sphagna are primitive mosses composed of a stem, and leaves of one layer of cells. There are no specialized tissues as in true mosses and higher plants. Sphagnum moss is composed of two kinds of cells: the living chlorophyll-containing cells which form a network, and in this network are imbedded a number of hyaline cells (see Plate 2-1). These hyaline cells have large cavities with their walls reinforced by lignin annuli and plates. A great number of small pores and a capacity to absorb water, and to conduct it from cell to cell, form the basis of the horticulturally advantageous properties of sphagnum peat. As the water is evaporated from sphagnum peat, some of it is always held inside the hyaline cells which, reinforced by the rigid annuli, will retain their shape. Evaporated water is replaced by air. It is obvious that by proper soil maintenance, optimum conditions in sphagnum peat for the intake of water, nutrients and oxygen for the plants can be achieved.

The water holding capacity of sphagnum mosses is obviously not a life function but a mechanical capillary function which is retained after the moss dies and as long as the hyaline cells are not destroyed. This means that after a degree of humification of about H5, the hyaline cells start breaking up and the sphagnum peat starts losing its special properties.

Sphagnum peats can commonly hold up to 15 times their weight in water with extremes to 30 times (Simard, 1972). The physical properties responsible for the high water holding capacity of sphagnum peat makes it ideal not only as a growing medium but also for uses as oil pollution control. In this case, with a suitable treatment and drying the peat can be made hydrophobic and oleophilic and thus, capable of absorbing large quantities of oil. Peat thus prepared is an excellent material for cleaning up oil leaked into waterways.

The low bulk density (dry) of less than 52.5 kg/m^3 up to only 97.5 kg/m^3 makes slightly humified sphagnum peat a bulky product for energy uses. From H5 upwards its value as a fuel grows with the increase in the bulk density and calorific value (Table 2-12).

TABLE 2-12. DEGREE OF HUMIFICATION AND BULK DENSITY OF SPHAGNUM PEAT (DRY WEIGHT).

Degree of Humification (von Post) (H)	Dry Bulk Densities (kg/m^3)	
	Mean	Limits
1	45	- 52.5
2	60	52.5- 67.5
3	75	67.5- 82.5
4	90	82.5- 97.5
5	105	97.5-112.5
6	120	112.5-127.5
7	135	127.5-142.5
8	150	142.5-157.5
9	165	157.5-172.5
10	180	172.5-

After Puustjärvi (1977).

With a proper fertilizing process the humic acids in peat change chemically so that peat particles are surrounded with carboxyl groups (–COOH) which have a capacity to release hydrogen ions. This results in creation of negatively and positively charged fields and forces of attraction and repulsion between cations and anions and a high cation

TABLE 2-13. CATION EXCHANGE CAPACITY OF IMPORTANT PEAT TYPES USED FOR HORTICULTURAL PURPOSES.

Peat Type	Degree of Decomposition	Exchange Capacity			
		Humic Acid	Humin	Total	Total Lime
		me/100g	me/100g	me/100g	kg/m³
Light sphagnum peat	H2	11	113	124	4.8
Dark sphagnum peat	H4	15	101	116	6.0
Very highly humified peat	H8	33	95	128	10.0

Values are for exchange capacity of humic acid relative to the weight of peat, in milliequivalents/100g (me/100g) and as lime in kg/m³ of peat at pH7. After Puustjärvi (1977).

exchange capacity between the plant and peat. This means that peat can store nutrient cations and, with proper treatment, release them for the plant's use.

A high cation exchange capacity is common to most sphagnum peat types, even the energy peats (H9 or more). However, the high water retention capacity combined with the high resistance of slightly humified sphagnum peats to degradation, make them more suitable as horticultural peat than well humified peats. The cation exchange capacity of sedge peats (peat composed mainly of sedges rather than sphagna) is 50-100 me/100g; considerably lower than that of sphagnum peats which vary from 100 to 160 me/100 g (Puustjärvi, 1977).

Usually peat starts to humify at an accelerated rate when mined from the bog and used as a growing medium or a soil conditioner. The rate of humification depends on the degree of aeration and practices such as fertilization. The increased degree of humification means an increased quantity of colloids derived from lignins in peat. This in turn means that the quantity of capillary water also decreases as the pore space decreases. As a result the peat loses some of its structural advantages for growth of plants. It is possible to slow down this process by extra liming and by the accompanying action of Ca and Mg to change humic acids to hydrophobic humates. Thus, the proportion of capillary water increases. By a suitable watering program this on the other hand can be kept relatively low and the pore space maintained due to a special property inherent to slightly humified sphagnum peat, i.e. its resistance to degradation. However, with the sedge peats the process of maintaining the structure cannot be held very long. Sphagnum peats contain lignin of different form and its content is low. So when sphagnum humifies, mainly only water and CO_2 are produced. The cellular structure, due to the strong structure of hyaline cells, is maintained even for several years. The resulting low quantity of colloids and a high pore space lead to a high proportion of capillary water and with the other qualities of sphagnum peat make it an excellent growing medium.

The permeability of peat is of a practical importance when considering the drainability of peatlands for peat mining or forestry and agricultural uses. On-site permeability may also affect the fluctuations in the water table in the drained peatland areas as well as the leaching of, for instance, fertilizers from cultivated peatlands into the adjacent environment.

Permeability varies with the degree of humification, peat type and also depth of peat. All these variables affect the influence that drainage may have on the environment. Plates 2-2 and 2-3 are examples of these factors. The permeability values of horticultural sphagnum peat are as high as 5 cm/min at H2 to as low as 0.01 cm/min at H8 (Plate 2-2). The permeability also varies with the depth of the samples. Near surface sphagnum peat at H3 has a permeability value of about 1.1 cm/min while at a depth of 120 cm it is about 0.4 cm/min (Plate 2-3).

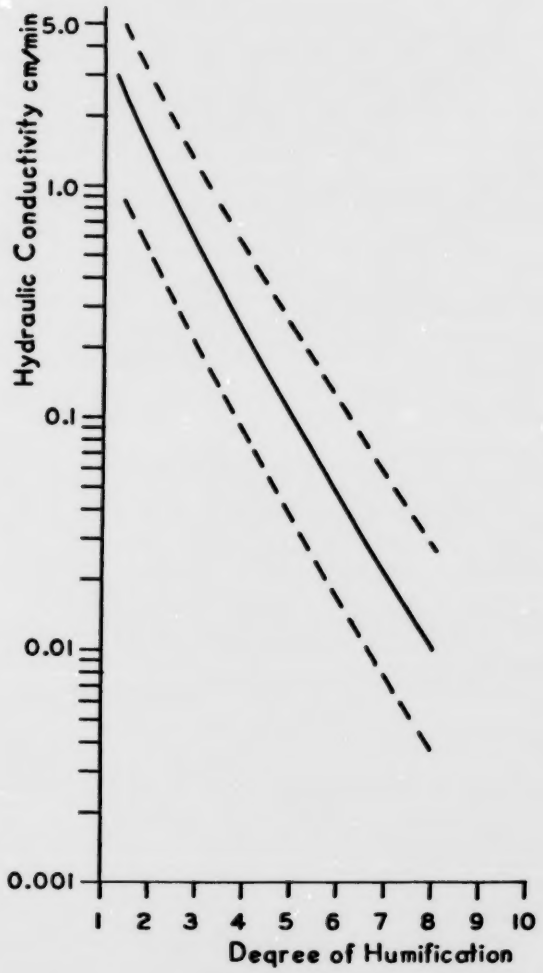


PLATE 2-2. HYDRAULIC CONDUCTIVITY OF SPHAGNUM PEAT IN VERTICAL DIRECTION VS. VON POST DEGREE OF HUMIFICATION.

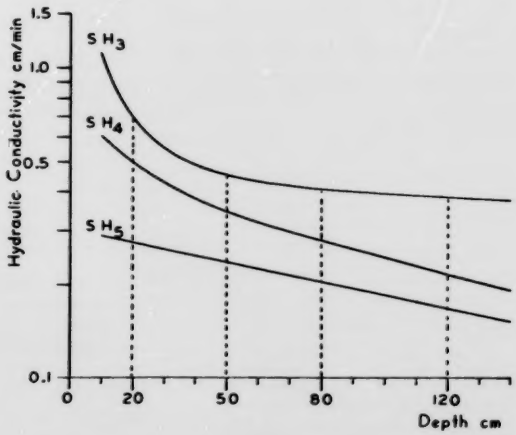


PLATE 2-3. HYDRAULIC CONDUCTIVITY OF SPHAGNUM PEAT IN THREE DEGREES OF HUMIFICATION VS. DEPTH.

The low nutrient content and the high permeability and high acidity (low pH) of sphagnum peat with low degree of humification make it less suitable for in-place agricultural purposes. The pH is commonly in the range of 3.2-4.0 and even as low as 2.5. Since the majority of the acids in peat are humic acids which are weak acids and dissociate as weak acids do, and are soluble in alkalines, the peat needs lime to activate it for plant growth. Also, slightly humified sphagnum peats are oligotrophic, partly due to their ombrogenic character, and require additional fertilization for optimal growth.

In practice these basic properties of sphagnum peat mean that the high pore space and the resistance to humification and the strength of the cellular structure of sphagnum peat makes it, dried, an excellent source of material for products such as insulating boards, etc. From the marketing point of view, the light weight, compressibility and capability of resuming the original structure after compression, allows slightly humified sphagnum peat to be transported economically over long distances in a relatively dry form.

As long as liming, fertilizing and watering can be done in a controlled environment (such as a greenhouse) sphagnum peats are excellent for horticulture, and are very economical and environmentally gentle as leaching of additives in the greenhouses can be controlled. *in situ*, however, the leaching cannot be controlled and the high permeability of sphagnum peat aggravates it.

The above implies that the surficial sphagnum peats with a low degree of humification (H1-3) will not really meet the economic or environmental requirements for in place use for agriculture or forestry, if the fertilization requirements and possible pollution are considered. However, well humified peats with their low permeability, high degree of humification, and higher nutrient contents render them good for *in situ* use for agriculture or forestry.

2.3.3 CHARACTERISTICS OF ENERGY PEATS

2.3.3.1 GENERAL

Energy peats are sphagnum peats with a degree of humification of H4 or greater, and sedge peat H3 or greater. Usually peats of high humification are found in locations where aeration is relatively good. Humification (degradation) progresses with time to advanced stages, even at depth, in bogs in areas of warmer climates such as parts of southern Ontario, U.S.A., and in some regions of the Tropics. Commonly, energy peats are at the bottommost part of the deposit and can create a problem of availability. The basic characteristics required of an energy peat are a high degree of humification, high bulk density, relatively low ash content, low content of potential pollutants such as sulphur and mercury, and a calorific value as high as possible.

2.3.3.2 BASIC COMPOSITION

Table 2-14 gives the basic composition of peat and various other fuels based on European information. Fuel peat has a carbon content of 50-60% (between wood and lignite), H content of 5.0-6.4% (partly the same range as wood and lignite), O content of 30-40% (between lignite and wood), N content of 1.0-2.5% (same general range as wood and lignite), and S content of 0.1-0.2%. The latter is considerably lower than that of coal or oil (2.0-2.8%). In Canada, according to Monenco's experience, the sulphur content of coal varies from about 0.2% in western Canada to about 5% in eastern Canada and appears to be sometimes lower than the European values given in Table 2-14.

The ash content of good fuel peat is only 2-10% (% of dry matter) or comparable with that of most coals. In Canada, ash content according to Monenco's experience, varies from 2-15% (measurements are for peat samples from Quebec and Saskatchewan). The melting point of peat ash is 1,100-1,200°C or within the same range as that of coal creating somewhat similar slagging properties as coal.

Volatiles are high, 60-70%, or higher than that of coal but lower than that of wood.

The bulk density at a 50% moisture content (a common moisture content as received at the plant for milled peat) for good fuel peat is 300-400 kg/m^3. However, in Canada this value ranges over wide limits from about 200 kg/m^3 in Saskatchewan up to 500 kg/m^3 in parts of Quebec. Ontario peats are expected to show a similar variation.

The following calorific values are largely based on European measurements as certain comparative values are not yet available for Ontario. However, considering the peat types and the environment of Ontario it is conceivable that the values shown here are comparable with those in Ontario.

The calorific values for fuel peat vary considerably with the moisture content. The most common operating moisture content is 50% on wet weight basis for milled peat and 35% for sod peat. The milled peat as mined moisture content may vary from 40-60%. However, anything over 55% is regarded as unacceptable for longer time periods. The lower values of 40% on the other hand create handling problems and a danger of explosion.

The calorific values of dry matter in peat vary from 4,700 to 5,100 kcal/kg (Table 2-14) or within the same range as for lignite. This compares well with Canadian values which vary, according to Monenco's peat studies in Saskatchewan

TABLE 2-14. COMPARISON OF VARIOUS FUELS.

	Heavy Fuel Oil	Coal (Bituminous)	Coal (Lignite)	Peat	Wood
C %	83-86	76-87	65-75	50-60	48-50
H %	11,5-12,5	3,5-5,0	4,5-5,5	5,0-6,5	6,0-6,5
O %	1,5-2,5	2,8-11,3	20-30	30-40	38-42
N %	0,2-0,3	0,8-1,2	1-2	1,0-2,5	0,5-2,3
S %	2,0-2,8	1,0-3,0	1-3	0,1-0,2	
Ash Content %	0,3	4-10	6-10	2-10	0,4-0,6
Melting Point of Ash %		1100-1300	1100-1300	1100-1200	1350-1450
Volatiles %		10-50	50-60	60-70	75-85
Specific Gravity kg/m^3	920-970	720-880	650-780	300-400	320-420
Effective Heat Value of Dry Matter, kcal/kg	9900-10000	6800-7900	4800-5800	4700-5100	4400-4600
Operational Moisture %	0,1	3-8	40-60	40-60	30-55
Effective Heat Value at the Lowest Operational Moisture Content, kcal/kg		6570-7640	2640-3240	2500-3000	2900-3040
Effective Heat Value at the Highest Operational Moisture Content, kcal/kg		6200-7220	1560-1960	1780-1960	1650-1740

TABLE 2-15. FUEL PEAT CLASSIFICATION FOR VAPO IN FINLAND.

Specified Characteristics		Contracted Class	Milled Peat		Sod Peat		Peat Briquettes
			Class J9	Class J11	Class P13	Class P15	
Moisture content	%	S	40-55	40-55	30-45	20-35	Z
Dry Vol. weight, lower limit	kg/m^3	S	appr. 160	appr. 180	appr. 180	appr. 180	Z
Approx. transport vol. weight	kg/m^3	S	250-500	300-500	250-450	250-400	Z
Effect. heat value of dry matter	kcal/kg	S	over 4700	over 4900	over 4900	over 4900	Z
Effect. heat value	kcal/kg	S	over 2000	2300-3100	2400-3800	3000-4400	Z
	MJ/kg	S	appr. 9±1	appr. 11±1	appr. 13±2	appr. 15±2	Z
—lower limit	$Gcal/m^3$	S	appr. 0.6	appr. 0.8	appr. 0.8	appr. 0.8	Z
Ash content, maximum							
—shipping lot	%	S	12	12	8	8	Z
—monthly average	%	S	6	6	6	6	Z
Ash quality							
—softening point		X	X	X	X	X	X
—melting point		X	X	X	X	X	X
—running point		X	X	X	X	X	X
—chemical composition		X	X	X	X	X	X
Grain size, sieve mesh	mm	S	100 x 200	100 x 200	—	—	—
Particle size, maximum	mm	S	—	—	150x200x500	X	Z
Quantity of wood	%	S	5	5	—	—	—
Quantity of peat crush	%	S	—	—	15	2	Z
Sulphur content	%	Y	Y	Y	Y	Y	Y
Additional information —production and transport mode —handling etc. if any		X	X	X	X	X	X

S: Is determined at the time of contracting
X: Is given if needed
Y: Is given if exceeds 0.3%
Z: Is determined later

and Quebec, from 5,100 kcal/kg to 6,100 kcal/kg respectively and in Ontario (Table 2-10) to 5,611 kcal/kg on a dry basis, greater than the values for lignite.

Calorific values of peat are dependent on moisture content, ash content, peat type, and the degree of humification. For instance, an increase in moisture content from 40% to 60% decreases the calorific values of peat up to 40% depending on the ash content. The decrease in the calorific value with an increased moisture content is not exactly linear. The reasons for this may be the effect of peat type and other variables. It is interesting to note that milled peat is usually delivered to the plant at a 50% moisture content (9.2 MJ/kg at 8% ash content) and sod peat at 30-35% moisture content (13.9 MJ/kg or more at 4% ash content).

2.3.3.3 SAMPLE FUEL PEAT SPECIFICATION

Table 2-15 is a sample of a fuel specification as prepared by VAPO (State Fuel Authority) in Finland for its peat suppliers for the power stations using milled peat as a fuel. These specifications are combined with others, describing in detail the methods of control sampling of delivered fuel peat, and the analyses and standards to be used. It is conceivable that a number of related standards and specifications will be needed and required in Ontario as the use of peat increases. ASTM is currently reviewing and developing peat standards and it is hoped that they shall have universal application.

2.3.4 RELATIONSHIP OF PEATLAND TYPES TO THEIR USE

Various peatland types as they are classified by their outer appearance, such as bogs, fens, marshes and swamps, and in a broader classification, ombrogenic versus minerogenic, are a reflection of conditions prevailing at present and affecting their development. While the climatic past history (10,000-12,000 years) has been variable and has caused changes in the composition of the peat deposits, a few general statements of the most likely uses for various peatland types can be made.

If the deposit is not thick enough, it cannot be used for peat mining. The shallowness of peat is often reflected in the bog type. Thus, marshes and swamps and often fens are best suited for agricultural, forestry and wildlife use. The peat in marshes may be shallow or non-existent. However, marshes are commonly flooded and, depending on the possibility of controlling flooding, they may be used for agriculture or forestry with some drainage. Often hydraulic conditions preclude the use of peat deposits where drainage is very difficult and the best use might be to leave them in their natural states.

Swamps on the other hand, appear in areas where there is no significant flooding. Swamps may be the first signs of the so-called primary paludification whereby waterlogged forest land is slowly being invaded by hydrophilic vegetation with ensuing accumulation of peat. Sphagna may be abundant and consequently the conditions will be more acidic than in the marshes. The swamps can be drained and with some fertilization turned into a productive agricultural or forestland. Marshes and swamps are considered eutrophic peatlands.

Fens, depending on their state of development, may be transitional between peatlands usable for peat mining and agricultural or forestry purposes as well as also between a non-energy and energy peat mining. Fens are generally examples of more advanced stages in the development than marshes or swamps and contain usually at least some peat. They are more acidic than swamps but less so than bogs. The peat is composed mainly of sedge peat types. Fens are relatively well aerated and contain a fair quantity of nutrients. As a result, the peat is quite often strongly humified. If the deposit is thick enough, fens are suitable for energy peat production. If the deposit is thin, the best uses would be forestry and agriculture.

Bogs are representative of ombrogenic conditions and raised bogs are the most typical of this type. Bogs are generally very deep (up to 10 m) and most commonly spread in the marine climatic areas with high surplus of water. They are best suited for the production of non-energy peats. However, in the deeper reaches of the bog, as well as along the edges, energy peats are common and

could be utilized after the surficial moss peat has been removed.

Bogs often form section of peat type complexes found inland. This intermixing of the types complicates the utilization picture and requires a thorough detailed survey of peatlands slated for a commercial use to enable the establishment of a proper plan.

2.4 DISTRIBUTION OF PEATLAND IN ONTARIO

2.4.1 GENERAL

The earlier comparison (Section 2.1) has shown that even the inferred estimates of the Ontario peat resources imply a large potential of peat in Ontario for both energy and non-energy uses.

In order to get one step further from these totally inferred estimates, a generalized peatland distribution map of Ontario has been produced accompanied by resource calculations (Plates A-2 to A-24 inclusive in Appendix A). It is hoped this map will give an impetus to further more detailed inventories to help proper peat and peatland utilization planning in the Province.

2.4.2 MAPPING METHODS

Monenco Ontario Limited has developed a four level peatland survey system. The survey methods used in the system are those often used internationally and it is hoped some of them will be standardized in the future. The scope of the present work has restricted the mapping to Level 1 as detailed in Table 2-16. This level of detail does not include fieldwork.

For the purpose of this study the main source of information used were literature, topographical maps (scale 1:250,000) and engineering geology terrain maps. These sources were supplemented by a number of checks on aerial photographs, 1:50,000 scale topographical maps and further contacts with other specialists working on peatlands in Ontario.

All the basic data was initially drafted onto 1:500,000 scale topographical maps. These maps were then reduced to 1:1,000,000 scale (Plates A-2 to A-24 inclusive in Appendix A).

Because of the scale factor, and the necessity to generalize information obtained from the topographical maps, only individual peatlands of 100 ha or more in size were usually included. In areas where a number of peatlands occur in clusters or in a contiguous network, bogs less than 100 ha may have been included in the generalized peatland area.

It was assumed that all the areas marked as open or forested wetland on the topographical maps were in fact peatlands. The only exclusions were areas obviously flooded depressions or marshes with no peat along lakes and streams. This assumption presumes that the operator of the stereoplotter doing the original topographic mapping was knowledgeable of landforms and included all the peatlands under the wetland symbol. However, it is obvious from the results, as seen on several maps, that both the human factor and the quality of original photography have affected the results.

The Ministry of Natural Resources is carrying out a mapping project in northern Ontario to produce engineering geology terrain maps at a scale of 1:100,000. Organic terrain is a mapping unit on the engineering geology terrain study maps and has been marked onto the peatland distribution map as peatland.

In addition to data base sources of the map, a number of literature [illegible] dealing with Ontario peatlands were reviewed and peatland information was plotted on the peatland map. Discussions on further information sources were conducted with the representatives of the Federal Government and the Ontario Centre for Remote Sensing, which is carrying out extensive survey programs in the Hudson Bay Lowland area on various aspects of peatland. Final details on the results of this work were available at the time of preparation of this work.

Hudson Bay Lowland area has been marked as a region of continuous peatland. It conforms in part to the region marked on 1:250,000 scale topographical maps as continuous wetland and on a wetland map in the National Atlas of Canada as a region with a 61-99% wetland coverage.

2.4.3 PEATLAND DISTRIBUTION

As a result of the data base characteristics a number of factors should be kept in mind when inspecting or using the peatland distribution maps. Topographical maps are basically compiled on a stereoplotter from properly corrected airphotos. In the areas of good access a large number of on-site checks can be made and made to verify the work done by the operator. However, these checks are made to measure or identify only easily definable objects such as portions of roads, buildings, etc. The outline of various landforms is more rarely checked. Also, in remote areas it is not practical. As a result, a topographical map detail represents the knowledge and the skills of the operator of the stereoplotter. This results in variation in the accuracy and quantity of information on sheets prepared by different operators. Other factors influencing this are the scale and quantity of the aerial photography. The aerial photographic scale varies and on a large scale it is possible to identify features such as peatland more accurately than on a smaller scale.

All this is evident on the generalized peatland distribution map of Ontario. Thus, for instance on the NTS Sheet Areas 52 SW, 52 SE and 43 SW there are abrupt changes in the distribution of peatland coinciding with the edges of the original 1:250,000 topographical map sheets. While the entire region of these sheets has an overall high density of peatland to continuous peatland areas it appears to be discontinuous and change abruptly.

Other anomalous concentrations are found along the main road and railway lines from Thunder Bay towards Manitoba border. It appears that there is a concentration of peatland along this corridor. However, it is customary to fly more frequent aerial photography at a large scale along road lines. As this results in better photography available at the time of mapping, the accuracy of recording wetlands, for example, has been higher along this corridor than elsewhere in the vicinity.

Often areas of anomalous concentrations are found south of Kapuskasing and in parts of southern Ontario (NTS areas 42 SE/32 SW and 31 SW). In these regions the additional information available from the engineering geology terrain mapping and the literature has added detail to the information available from 1:250,000 maps alone.

Another widespread anomaly is the apparent lack of peatland in large sections of the Precambrian Shield Region (e.g. Plates A-3, A-4, and A-19) and its apparent abundance near the transition from the Precambrian to Hudson Bay Lowland area (Plates A-9, A-20, A-21, and A-22). This may have been caused also by the fact that in the Precambrian Shield areas the bogs tend to be small, tree covered and confined to depressions while near the Hudson Bay Lowland Region they are less confined and open and thus, more readily identifiable by the stereoplotter operator.

As a result, it may be that in some parts of Ontario, the peatland distribution map has a somewhat over-representation, and in other parts under-representation of

TABLE 2-16. LEVELS OF INVESTIGATIONS FOR PEAT RESOURCE ASSESSMENTS.

LEVEL 1:	PRELIMINARY PEATLAND SURVEY USING MAPS, INFORMATION FROM LITERATURE, AND AIRPHOTO SPOTCHECKS The purpose of the Level 1 survey is to establish a preliminary list of all probable peatlands by using existing maps and checking a number of locations on aerial photographs. The information obtained from maps is supplemented by that from literature. Resource calculations are preliminary and based on interpolation of values gleaned from the literature.
LEVEL 2:	PEAT AND PEATLAND SURVEY BY AIRPHOTOS AND OTHER REMOTE SENSING TECHNIQUES The purpose of a Level 2 survey is to compile a list of all the peat deposits of the Province by using aerial photographs as the main source of information. Each deposit is located, numbered and plotted on a large scale map. The surface area of the open and treed portions is measured, and the extent of ponding is estimated to provide useful information regarding the suitability for development. The range of peat thickness and the distribution of peat types is determined by visiting a limited number of representative deposits in various parts of the Province. Based on the results of this ground truthing, and on knowledge of peatland airform patterns, the thickness of peat and distribution of peat types for the rest of the deposits is inferred. A Level 2 investigation gives a relatively accurate picture of the peat resources for the Province. The results of a Level 2 investigation should be regarded as a basis for the selection of areas with potentially usable peatland resources, warranting a further detailed survey for final selection of a source of peat for a specific project(s). A Level 2 investigation for the Province can be performed in 1-2 years depending on the degree of detail and accuracy needed.
LEVEL 3:	DETAILED GROUND SURVEYS Level 3 surveys can be done either before, concurrently with, or after Level 1 and 2 work depending on how urgently the information is needed. Usually this step follows a Level 2 survey and concentrates on regions found suitable for further investigations, or for establishment of a project. The purpose of this step is to select a number of deposits for final development. This work involves extensive study including sampling of deposits at a suitable density along a grid. The time required varies depending on the size, access and depth of the deposit. Generally, deposits smaller than 100 ha in size can be covered at a rate of 20 ha/day and larger ones, depending on the homogeneity of the deposits, up to 60 ha/day. A Level 3 survey gives detailed information on the size of the deposits, distribution, quantities and qualities of peat types, the basic chemical and physical characteristics of peat in the investigated deposits, the drainability, access, land ownership and other information affecting the suitablilty of the deposits for development.
LEVEL 4:	SITE-SPECIFIC, PROJECT-ORIENTED ASSESSMENTS The final step in developing a peat deposit for an industrial use is to make a detailed sampling assessment of the peat thickness, distribution of peat types and conduct a surface elevation survey. This work can be carried out on a 100 m grid to enable the establishment of a properly located drainage plan, and the most efficient mining plan. This type of work is done for deposits to be taken into use immediately and is expanded to cover other deposits in the region as the need arises. In connection with this work, a large number (e.g. 1 core/10 ha) of samples for chemical and physical analyses are taken to facilitate planning of the mining sequence.

peatland. However, on average the total calculated area should come near the actual values. An accurate assessment of peatland coverage can be achieved only through a thorough Level 2 survey (Table 2-16) of large scale (1:10,000-1:20,000) airphotos with ground truthing.

Due to the nature of the data base, these maps cover the Ontario peatland both in the biological and geological sense. A further check of Engineering Geology Terrain Maps has shown that their map unit "Organic Terrain" frequently covers river valley, lakeshore and floor plain marshes and swamps with no peat. They also occasionally include wet areas created by beavers.

2.4.4 RESOURCE CALCULATIONS

2.4.4.1 METHOD OF DETERMINATION

On a rather arbitrary basis, the Province was divided into four regions: Hudson Bay Lowlands, Western Shield Region, Eastern Shield Region and Southern Lowlands (Plate 2-4) and the peat resource estimates were made separately for each of the regions. In addition to the regions, separate calculations were made for permafrost (see glossary) and non-permafrost areas within the Western Shield Region and the Hudson Bay Lowlands. For each region all the individual peatlands or groups of peatlands were counted and their approximate surface areas measured on the 1:500,000 scale base maps.

Based on references in the available literature, the average depth of peatland in each region was determined and also the ratio between moss peat and fuel peat was estimated. This ratio was not readily determinable because of the lack of sufficient data and has been adjusted based on known ratios elsewhere in Europe and in Canada (New Brunswick) (Korpijaakko, E., 1975).

Based on the previous information, preliminary peat resource estimates for the Province of Ontario were determined as described below.

2.4.4.2 RESOURCE QUANTITIES

AREAS OF PEATLAND. A total of about 6,625 individual peatlands and groups of peatlands were counted on the Preliminary Peatland Distribution Map of Ontario. Due to the nature of the base data, no division of the peatlands quantitatively into peatland types such as bogs, fens, marshes and swamps was carried out.

By size, about 2,000 were 100 ha to 200 ha in size, and 2,400 were 200 ha or more in size. In most cases they represented individual deposits. About 1,500 were estimated to be at least 800 ha in size. Of these, a portion was composed of closely grouped peatlands and the rest were individual deposits. About 600 were estimated at 3,200 ha, and 100 at 12,800 ha or more in size. The latter two groups were almost entirely representative of closely grouped individual deposits or part of the area marked as areas of "continuous peatland" on the map. The total area of the individual or groups of peatland was calculated to be about 5,142,000 ha giving an average size of about 776 ha (Table 2-17).

The total area of unconfined (continuous) peatland was calculated to be about 20,751,000 ha. The grand total for the entire Province is thus, 25,893,000 ha. This is considerably larger than the 16 million ha given by Tibbetts (1980) and should be a step further from the earlier inferred estimates. Of this total, about 16,043,000 ha are estimated to be within permafrost regions and 9,850,000 ha outside. The latter area represents the potential usable area using existing conventional peat mining systems.

VOLUMES AND TONNAGES OF PEAT. Calculations were based on the information in the literature (Anrep, 1908-1914, 1919, 1920, 1921; Haanel, 1924, 1925; Auer, 1927, 1928, 1930; Graham and Tibbetts, 1961, 1965; Graham, 1979, etc.). The average peat thickness for the regions are as shown in Table 2-18.

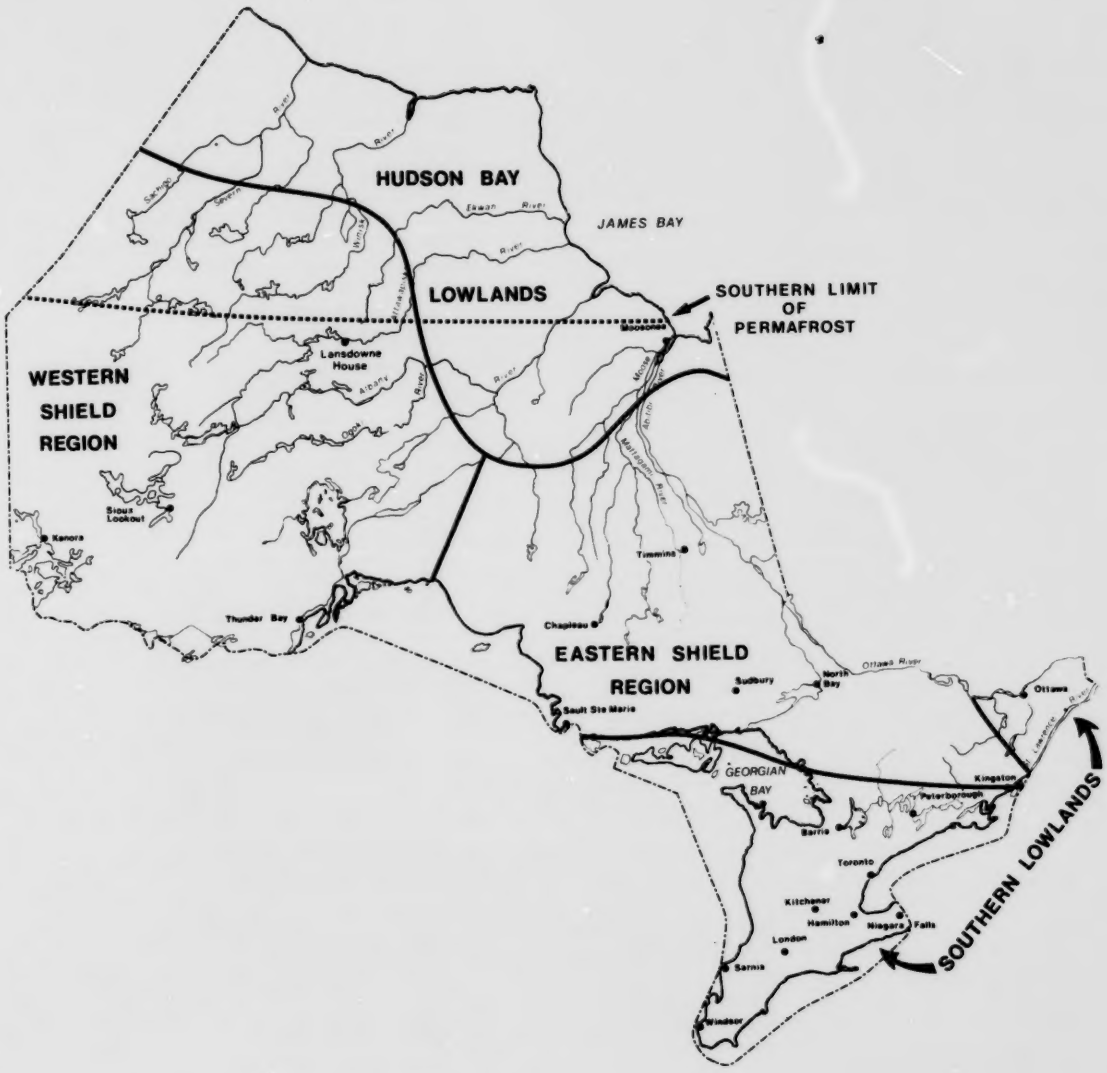


PLATE 2-4. GEOGRAPHIC REGIONS OF ONTARIO.

TABLE 2-17. AREA OF PEATLAND RESOURCES IN ONTARIO.

GEOGRAPHICAL AREA	AREA OF PEATLAND (ha)										
	PERMAFROST			NO PERMAFROST							
	Unconfined Peatland	Individual Peatland	Total Peatland	Unconfined Peatland	Individual Peatland	Total Peatland	Number of Peatlands Over 100 ha	Average Size Of Each	Total Area Individual	Total Area Unconfined	Total All Peatland
HUDSON BAY LOWLANDS	14,100,000	15,000	14,115,000	5,600,000	160,000	5,760,000	175	1000	175,000	19,700,000	19,875,000
WESTERN SHIELD COUNTRY	700,000	1,228,000	1,928,000	,50,000	2,259,000	2,309,000	4680	745	3,487,000	750,000	4,237,000
EASTERN SHIELD COUNTRY	0	0	0	301,000	1,196,000	1,497,000	1495	800	1,196,000	301,000	1,497,000
SOUTHERN LOWLANDS	0	0	0	0	284,000	284,000	275	1035	284,000	0	284,000
TOTAL	14,800,000	1,243,000	16,043,000	5,951,000	3,899,000	9,850,000	6625	776	5,142,000	20,751,000	25,893,000

NOTE: — Land area for unconfined peatland is adapted after "Cover and Landform, Cover and Climatological Studies Series, Department of Environment, Atmospheric Environment Service.
— Individual peatland area is measured from 1:250,000 scale topographical maps, 1:100,000 scale engineering geology terrain maps, and spot checks on 1:50,000 scale topographical maps and 1:20,000 air photos.
— The southern limit of any occurrence of permafrost coincides approximately with the 30°F (−1°C) average annual isotherm of air temperature.
— Most peatland areas of about 100 ha and over were identified and counted, peatlands of less than 100 ha in size have been omitted.

TABLE 2-18. VOLUME OF PEAT IN ONTARIO

GEOGRAPHICAL AREA	VOLUME OF PEAT ($m^3 \times 10^6$)							AVERAGE DEPTH OF PEATLAND (m)			
	PERMAFROST			NO PERMAFROST				PERMAFROST		NO PERMAFROST	
	Unconfined Peatland	Individual Peatland	Total Peatland	Unconfined Peatland	Individual Peatland	Total Peatland	Total for all Peatland	Unconfined Peatland	Individual Peatland	Unconfined Peatland	Individual Peatland
HUDSON BAY LOWLANDS	113.0	.2	113.2	73.0	2.4	75.4	188.6	.8	1.3	1.3	1.5
WESTERN SHIELD COUNTRY	5.6	16.0	21.6	.7	47.4	48.1	69.7	.8	1.3	1.3	2.1
EASTERN SHIELD COUNTRY	0	0	0	3.9	27.5	31.4	31.4	—	—	1.3	2.3
SOUTHERN LOWLANDS	0	0	0	0	7.7	7.7	7.7	—	—	—	2.7
TOTAL	118.6	16.2	134.8	77.6	85.0	162.6	297.4	.8	1.3	1.3	2.2

NOTE:Peat depth averages are based on a literature review of available fieldwork reported in journals and Government reports.

Based on the surface area values measured on the 1:500,000 base map and the interpolated average thicknesses, *in situ* volumes were calculated as shown in Table 2-18. The total peat volume in Ontario is about 297.4 $\times 10^9$ m^3. Approximately 134.8 $\times 10^9$ m^3 of this is in the permafrost zone and using conventional peat mining systems, must be considered unavailable. The balance, 162.6 $\times 10^9$ m^3 is outside the permafrost and potentially usable.

The largest usable* peat resources are in the Hudson Bay Lowland area and amount to 75.4 $\times 10^9$ m^3 of peat covering 5,760,000 ha. However, due to an estimated low average thickness of about 0.8 m, large areas of the deposits may not be mineable and would constitute peatlands for non-energy uses such as forestry.

Second in terms of volume and surface area is the Western Shield Region with a total of 48.1 $\times 10^9$ m^3 of peat covering 2,259,000 ha. In this region the average thickness has been established from 1.3 to 2.1 m. The latter figure applies to the more southern region where peatlands occur. Mineability in the southern area is limited mainly by access. Large concentrations of peatlands occur along the southern border of the Province, as well as along the main transportation corridor from Thunder Bay to Kenora and represent a resource potential worth further detailed inventory work.

The Eastern Shield Region has peat resources with total volume estimated to be 31.4 $\times 10^9$ m^3 of peat covering 1,196,000 ha. Some of this (300,000 ha, 3.9 $\times 10^9$ m^3) is part of the thin unconfined (continuous) southern peatland. The rest is composed of individual or groups of individual deposits with an average thickness of 2.3 m. The potential for commercial use is attractive, especially in industrialized regions, such as Sudbury and also near remote communities further north, where large peatland areas with large quantities of peat occur.

The Southern Lowlands have the smallest quantity of peat, mainly because the region is not as large in size as the others and does not contain unconfined peatlands. However, the potentially usable area of 284,000 ha with a total of 7.7 $\times 10^9$ m^3 of peat averaging 2.7 m in thickness represents a significant resource. Its value is increased also by favourable climatic conditions and relatively short transportation distances to potential markets. The largest deposits in this region are concentrated in a zone south and northeast of the Precambrian Shield running from Ottawa towards Lake Simcoe (NTS Areas 31 SE, 31 SW). This region has a number of sizeable deposits with very good potential for commercial use.

There are insufficient detailed peat surveys in Ontario to estimate the moss peat/fuel peat ratio in detail. The peatland development and peat types in Ontario are similar to those in northern Europe and New Brunswick and show many analogous features. Based on this it may be assumed that ratio of average fuel peat thickness/average thickness of the total deposit = 0.6. Assuming that this ratio can be applied, in Ontario moss peat and fuel peat resources can be calculated for the Province as shown in Table 2-19. Assuming that on an average the "as mined" bulk density of moss peat is 200 kg/m^3 and fuel peat is 300 kg/m^3 (at 50% moisture on a wet weight basis) the tonnages can be estimated for the peat regions south of the southern limit permafrost.

*Usable peat—considered for this study to occur south of the southern limit of permafrost.

2.4.4.3 EXPLOITABLE RESOURCES

On average, 1 tonne of oil has approximately the same heating value as 3.7 tonnes of peat (at 50% moisture content). Thus, the total *in situ* fuel peat resources are roughly equivalent to 11 billion tonnes (72 billion barrels) of heavy oil. It has to be kept in mind that all these figures refer to the total *in situ* resources. A certain percentage has to be discounted for a number of reasons, including thinness of the deposit, poor access, poor drainability, poor local weather conditions, non-contiguity of the peatlands, or when contiguous they form narrow networks of bogs unsuitable for mining operations, environmentally sensitive areas and chemically unsuitable peat types. Even if by conservatively estimating that only half the total tonnages are usable, it would still amount to about 20.84 billion tonnes of peat.

2.4.4.4 DISTRIBUTION OF PEAT AND PEATLAND TYPES IN ONTARIO

There are no comprehensive surveys on the distribution of peat and peatland types in Ontario. Basically a gross generalization can be made that the peats and peatlands of Ontario are largely a transition between the Quebec-Maritime ombrogenic peatland types (which contain sphagnum peats, having high acidity and low nutrient level and low degree of humification) and the central Canadian fen type peatlands common in Manitoba and Saskatchewan. In fen areas, sedge peats, low acidity and eutrophic conditions prevail. In Ontario, very typical raised bogs with distinct concentric ridge-flashet patterns are rarer than in the east. Large portions of peatlands are slightly wooded with relatively thin sphagnum peat layers and a thicker sublayer of a mixture of forest sedge and sphagnum peats. This layer often is highly humified and suitable for energy purposes. The exception is the Hudson Bay Lowlands which have permafrost and unconfined (continuous, contiguous) peatland. Here large areas of slightly humified shallow (0.5-1.5 m) sphagnum peats are encountered.

In the Shield country a large number of peatlands formed in depressions are encountered. They are often characterized by streams dissecting them, high water tables, and occasionally dense tree cover. Due to poor drainability and high moisture content and narrowness, they often are best suited for wildlife use. The cover varies from FI to EFI and near the edges BEI and DEI. The peat depths are very variable, from 0.5 m to 3 m and more. Often the *in situ* water content is high. Sedge peats are predominant in the wetter bogs while sphagnum peats are common in drier bogs.

TABLE 2-19. PEAT QUANTITIES IN ONTARIO PEAT REGIONS (SOUTH OF SOUTHERN LIMIT OF PERMAFROST).

	VOLUME		TONNAGE	
	Moss Peat $10^9 \times m^3$ *in situ*	**Fuel Peat** $10^9 \times m^3$ *in situ*	**Moss Peat** TONNES $\times 10^9$ *(at 50% moisture)*	**Fuel Peat** TONNES $\times 10^9$ *(at 50% moisture)*
Southern Lowlands	3.08	4.62	.62	1.39
Eastern Shield Region	12.56	18.84	2.51	5.65
Western Shield Region	25.24	22.86	5.05	6.86
Hudson Bay Lowlands	30.16	45.24	6.03	13.57
	71.04	91.56	14.21	27.47

Total estimated Ontario peat resources = 41,680,000,000 tonnes south of the southern limit of permafrost.

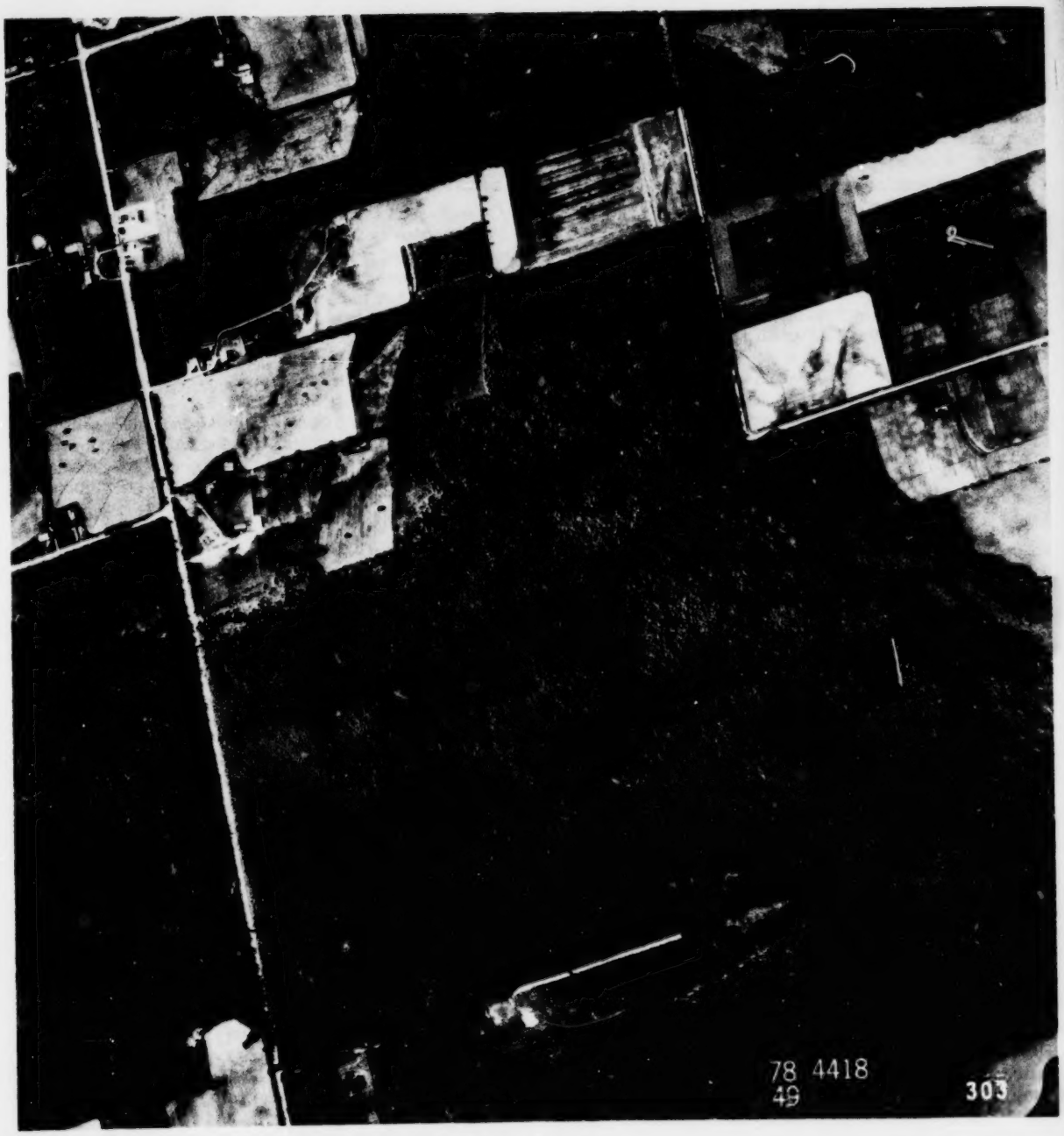


PLATE 2-5. PEATLAND IN SOUTHERN ONTARIO NEAR LAKE SIMCOE.

Plate 2-5 is an example of a typical peatland in southern Ontario near Lake Simcoe, south of the Precambrian Shield. In this area the peatlands are often relatively large, filling shallow depressions along ancient stream beds or valleys or located in the depressions created by the latest glaciation. Peat depths occur occasionally to 6 m. The most common peat type in this location is relatively well humified (H5) sphagnum-sedge peat near the surface and sedge peat with a high degree of humification at depth (H5-9). The Radforth cover classification is commonly BEI to AEI and DEI at the edges. The airform pattern is stipploid. The dense tree cover and high occurence of large chunks of wood in peat may hamper mining of peat.

PLATE 2-6. PEATLAND IN THE SOUTHERN PART OF EASTERN SHIELD REGION.

Plate 2-6 is an example of a confined peatland in the southern part of Eastern Shield. In this region peat is often confined to depressions created by glaciation. Quite frequently the bogs form a contiguous network and may be mined although individual bogs are quite small. Often drainage may be a problem, as shown in the photo, where the stream floods the areas.

PLATE 2-7. PEATLAND IN THE EASTERN REGION OF ONTARIO.

Plate 2-7 is an example of a peatland in the Eastern Shield Region of Ontario. In this area the peatlands show a tendency of becoming unconfined and covering large areas. Sphagnum peat is more common. Tree cover is widespread but the trees are smaller than in the south and are mostly black spruce (Radforth cover BEI). The depth of peat is sufficient for mining. Drainage may create problems because the deposits are often confined to depressions.

PLATE 2-8. PEATLAND NORTH OF KENORA.

Plate 2-8 shows the contiguity of peatland north of Kenora. In this general area, access and drainage may create problems due to remoteness and location of deposits in depressions. However, the resource is substantial and the peat types should support various types of industry.

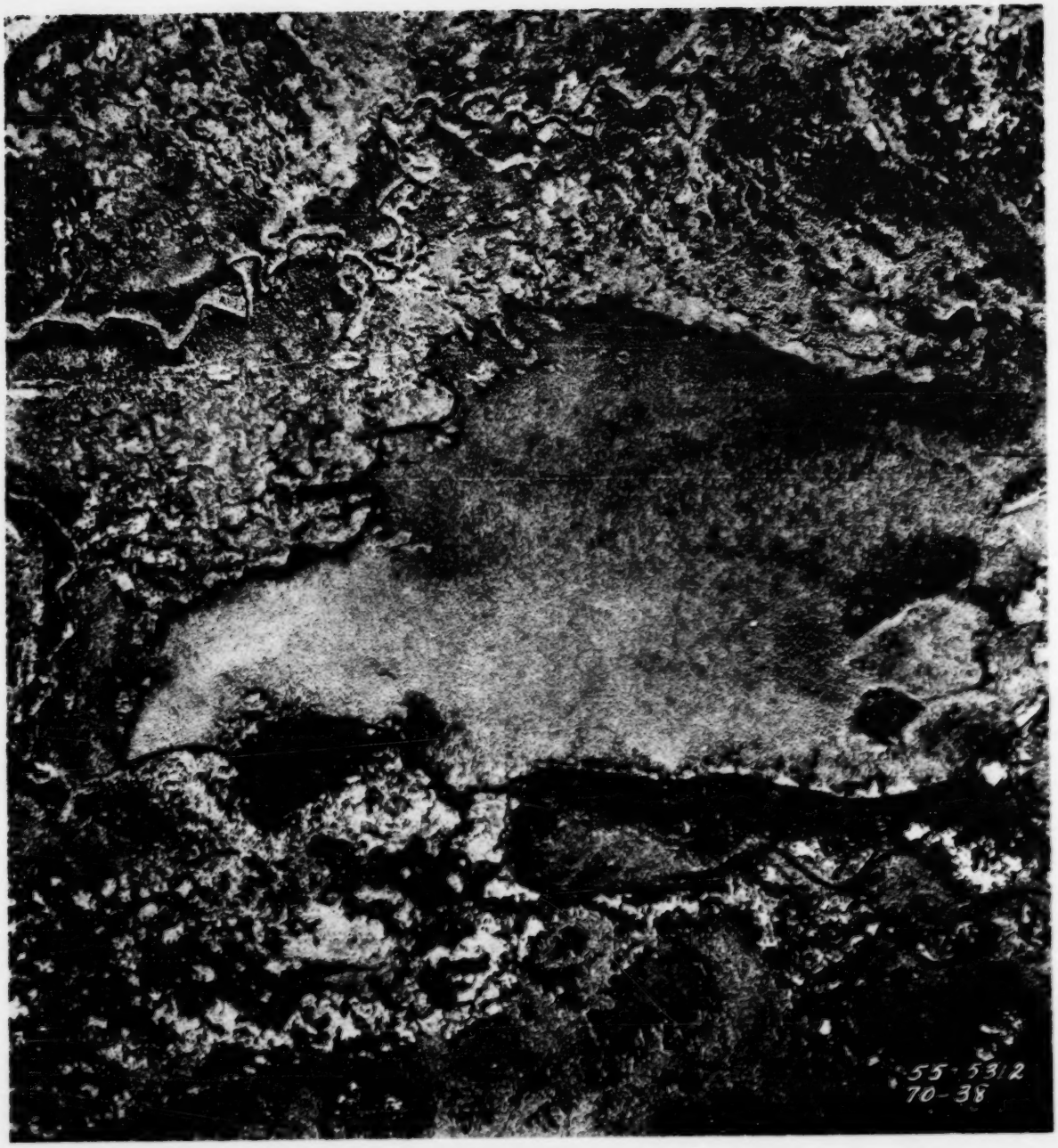


PLATE 2-9. PEATLAND CLOSE TO THE SOUTHERN LIMIT OF PERMAFROST.

Plate 2-9 shows a peatland area further to the north, close to the southern limit of permafrost. The peatlands are very flat and are composed of large uniform areas (outlined) with innumerable numbers of small pockets of peat between them. The region starts to show clearly signs of an unconfined nature. Mining may be marginal due to the shallowness of peat, poor access and drainage as well as some areas because of a severe climate.

PLATE 2-10. HUDSON BAY LOWLAND CONTINUOUS PEATLAND.

Plate 2-10 is a typical example of Hudson Bay Lowland continuous peatland. The peat is shallow and permanently frozen. Drainage in some areas is impossible. The occasional deeper pockets or hummocks of peat are widely spread and to attain uniform production on these areas would be difficult. This pattern is composed of reticuloid and marbloid airform patterns, the latter of which is an indication of permafrost. The best use at present in these regions appears to be to leave the areas in their natural state.

Typically,the transition zone from the Precambrian to younger formations display large peatlands well suited for commercial utilization as is seen on the NTS Sheet areas 31 SE, 42 NE, 43 SW, 53 NE with large individual and grouped peatlands as well as the onset of the unconfined peatland of Hudson Bay Lowlands. These regions are located in the general Ottawa area and along a corridor from St. Catharines to northeastern Ontario south of Hudson Bay Lowlands.

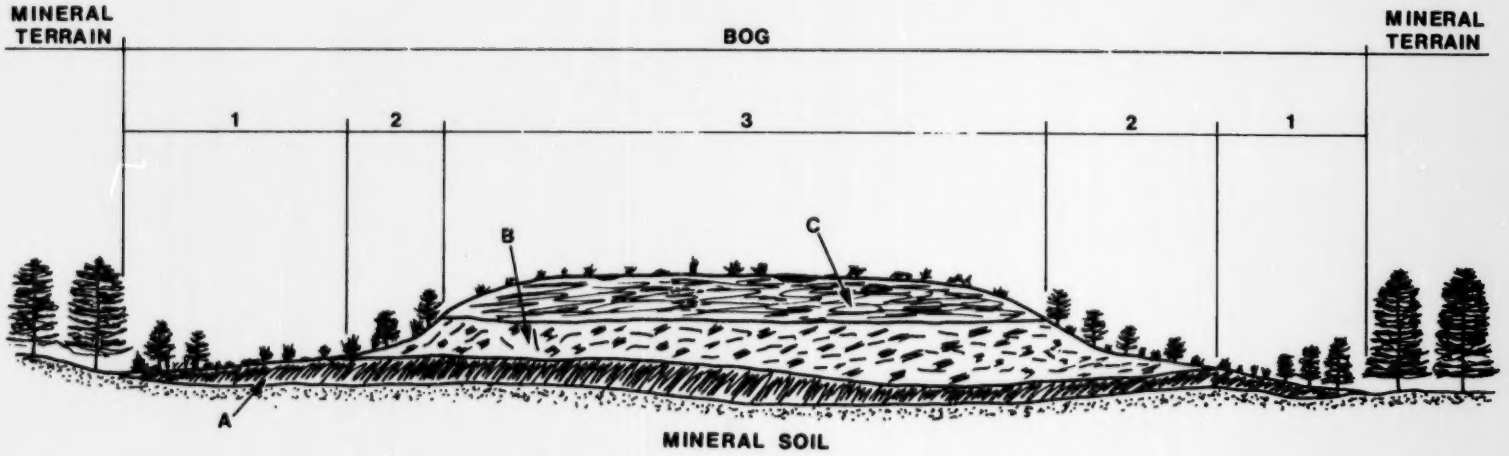


PLATE 2-11. SIMPLIFIED DIAGRAM OF OMBROTROPHIC BOG.

1. **Lagg Zone:** This is minerotrophic and constitutes the area of active paludification. The vegetation is composed of stunted trees, herbs, etc. near edges, sedges and sphagna in the middle and increasing quantities of sphagna and shrubs towards the center of the bog. The peat is sedge-sphagnum peat with a moderately high degree of humification (H4-6). (A)
2. **Slope Zone:** This zone is semi-ombrotrophic. Due to improved drainage microbial activity is increased temporarily and small stunted tree growth is supported. The surface vegetation commonly is composed of stunted black spruce, various shrub and sphagna. Peat is predominantly composed of sphagnum with remnants of wood (stumps) with a moderate degree of humification (H2-5). (B)
3. **Central Zone:** This is the zone of mature raised bog characterized by poor drainage and ponds and ridges. Vegetation varies from shrub-sphagnum cover to pure sphagnum and occasional areas of cotton grass. Peat is predominantly composed of sphagnum with a low degree of humification (H1-3). (C)

Note: Vertical scale exaggerated for pictorial clarity.

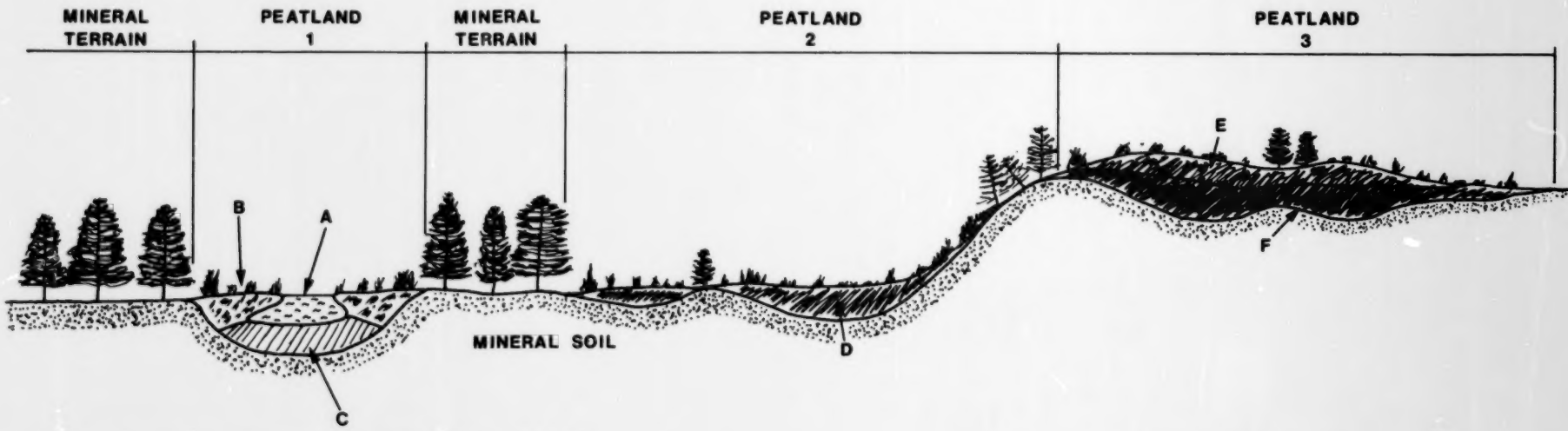


PLATE 2-12. SCHEMATIC DIAGRAM OF MINEROTROPHIC PEATLAND.

1. Pond being filled in by vegetation.
   A = open water
   B = semiaquatic vegetation, partly floating, forming peat.
   C = submerged aquatic vegetation and debris falling from the floating mat forming peat.
2. Peatland formed by paludification of forest through spill-off effect from adjacent peatland (3). Upslope the vegetation is composed of sphagna in the ground story and dying trees as the higher vegetation. Downslope the peat is already established and is covered by sedge-herb-shrub vegetation. Peat is composed of a variety of types mainly predominated by sedges. Degree of humification is generally high (H5-8). (D)
3. Peatland formed on higher ground in waterlogged conditions. Vegetation consists of occasional islands of low trees in large areas of sedge dominated vegetation. Peat is predominantly composed of sedge types near the surface and of forest peats near the base. The degree of humification varies from H3-5 near the surface (E) to H8-9 near the base. (F)

Note: Vertical scale exaggerated for pictorial clarity.

2.5 SUMMARY OF THE PEAT RESOURCES OF ONTARIO

Previous information on the extent of the peatlands of Ontario has been varied. According to data published by Simard in 1972 only 200 ha of peatland was being exploited in Ontario. No surveyed or additional exploitable area was reported (Table 2-1). Data published in 1980 by Tibbetts (Table 2-2) estimated potential inferred peat resources for Ontario at 16 million ha, or $27,580 \times 10^6$ tonnes at a 50% moisture content. The actual measured area was reported to be 62,000 ha or about 135×10^6 tonnes of peat (50% moisture content), only 0.4% of the estimated total peatland. Data published by Kivinen *et al.* in 1980 on world peat resources, estimated the resources of Canada at 170 million ha of peatland, the largest in the world.

According to the present work, the total peatland area of Ontario is about 26 million ha (potential inferred peat resource). A total of nearly 9.9 million ha (about 42 billion tonnes) of peat are located south of the southern limit of permafrost. This is equivalent to about 26.6 billion barrels of oil if all of the peatland were assumed to be available for energy production.

If the above reported surveyed area of 6,200 ha for Ontario is accurate, then only about 0.2% of the total peatland area of Ontario has been surveyed. Also, if the above reported 200 ha of exploited peatland in Ontario (Simard, 1972) is accurate, it represents less than 0.001% of the total peatland area.

The total of 26 million ha of peatland places the Province third (excluding the rest of Canada) in terms of world peat resource statistics, together with Indonesia (Table 2-3).

A survey of literature on the general physical and chemical properties of Canadian and Ontario peat indicates that the values for Ontario peat is comparable with data published for northern European and Irish peats. Ontario peat and peatlands should be suitable for both horticultural and fuel peat production, as far as quality is concerned. Also, although the published information on peat in Ontario is voluminous, it covers mainly special research-oriented or site-specific work and does not give a comprehensive account of the general distribution of the different peatland and peat types. Standard uniform classification systems have not been used. A modified von Post system is recommended for peat classification as well as that proposed by Jeglum *et al.* (1974) for peatland classification for peatland inventory work in Ontario.

Given the magnitude of the Ontario peat resource and its potential for development applications, through an orderly and properly planned approach, it is clear that a resource survey and inventory is required. The present study and generalized peatland distribution map, represent only a first step in the attempt to locate and quantify Ontario peatlands in a detailed manner.

PART 3
Peat Mining

3.1 PREVIOUS PEAT MINING IN ONTARIO

Systematic bog surveys were started in 1908 by the Federal Department of Mines which by 1930 had mapped about 130 bogs in the more accessible areas of the Dominion (Natural Resources Intelligence Service, Ottawa, 1929). Generally, production quantities prior to World War II were insignificant and most production bogs were private family operations producing litter peat for stables. Commercial peat production in Ontario during 1944 was reported to be about 10,000 tonnes, which is actually greater than the 1979 production level of only 6,000 tonnes.

Peat production was usually by hand cutting along excavated cutting lines. The diggers worked singly or in pairs and cut sods in blocks to a size of about 6 by 6 by 18 inches. The sods were then spread on the field to dry. Once the surface of the block was partially dry, the blocks were stacked in loose piles on racks to permit air to freely circulate. Air drying to about 30% moisture took up to 3 weeks. Harvesting was usually by narrow gauge rail systems except for the bogs where the surface was firm enough to support tractors and dump wagons. It is reported that peat operators in western Ontario used tractor/wagon harvesting equipment.

Records of peat production and equipment used in Ontario are incomplete, however, Table 3-1 shows that the current interest in peat in the Province is not new.

At present, horticultural peat is produced commercially* near Welland (Atkins and Durbrow Limited) and Cornwall (Diamond Peat Moss Limited), in southern Ontario and near Fort Frances (Arctic Peat Moss Limited) in western Ontario, however, the total annual production is reported to be still less than 10,000 tonnes.

*Statistics Canada for 1980 Production year.

TABLE 3-1. PREVIOUS PEAT OPERATIONS IN ONTARIO

County	Operation
Stormont County	Newington bog, the hydro peat mining method was tested for the production of humus fuel peat.
Prescott County	Alfred bog, horticultural peat production for a short period starting in 1941. Fuel peat production trials.
Leed County	Brockville bog, fuel peat production about 1910.
Victoria County	Victoria Village bog, block cut moss peat production in 1940.
Hamilton-Wentworth	Westower bog, produced humified peat and marsh during the 1940's. Was one of the largest Ontario producers.
Niagara	Welland bog, block cut sod peat operation in combination with bog railway haulage of peat during the 1940's, now uses the vacuum peat harvesting method.
Dufferin County	Amaranth bog, was worked experimentally by the hydro-peat process during the 1940's.
Wellington County	Luther bog, during the 1940's the bog was worked experimentally for the production of chemicals from fuel peat by a hydro-peat production method.
Kent County	Rondeau bog, partially was under production by C.I.L. for peat humus as a fertilizer filler. Ridge peat mining method was used (circa 1940's).
Rainy River	Crozier bog, under production for block cut sod peat in 1942 by the Arctic Peat Moss Corp. Limited. Utilized tractor/trailer peat haulage.
Rainy River	Polar Bear bog, under production for block cut sod peat in 1942. Produced horticultural and litter grade peat moss.

Source: "Peat Moss Deposits in Canada", H.A. Leverin, Canada Department of Mines and Resources, 1946.

3.2 CLIMATIC CONSIDERATIONS

3.2.1 GENERAL

Climate is one of the main physical controls determining the feasibility of carrying out peat mining operations. The main climatic factors affecting the determination of peat development, either individually or in combination are temperature, precipitation, sunshine, wind, and the length of the frost-free period. Other factors, such as potential evapotranspiration and average annual water deficiency are useful as indicators for the suitability of the regional climate for peat mining. The consideration of all these factors must be subject to a careful interpretation, in that climatic conditions may indicate that a specific area in Ontario may be suitable for a peat mining operation, day to day weather may hamper or even occasionally preclude the operations. Consequently, a necessary prerequisite to any peatland development scheme is a detailed analysis of local climate and weather over the production period considered. This develops fundamental input for determining size of operation, selection of mining methods, equipment, and possibly peat products.

Currently, there is no detailed information available which relates climate to peat production rates. Studies have been suggested to develop an index based on climate and other factors to determine the suitability of a particular area for producing peat. Some work is being carried out in Finland at present to correlate climate, weather and peat production, not only for use in the planning of future operations but as an aid in daily production planning. Some peat mining operators have arranged with the government meteorological service to have specially prepared weather forecasts broadcast to suit their specific operating and production planning needs.

It is beyond the terms of reference of the study to carry out a detailed analysis of climate. However, it is considered to be of importance to pursue a climatic comparison, in preliminary terms, of the Province with the peat producing regions of Finland as a means to perceive the peat production potential for certain regions of the Province of Ontario.

3.2.2 CLIMATE OF FINLAND

Finland, the world's most northerly country and lying between the 60th and 70th Parallels of North Latitude, has a total surface area of 337,436 km^2. As a result of Finland's proximity to the Atlantic Ocean and the Asian land mass, its climate tends to be transitional between the marine climate of the Atlantic coast and the continental climate of Eurasia. As a consequence of these influences, the summers on the west coast tend to be warm and hazy, while frequent afternoon thunderstorms are characteristic of eastern Finland. During the summer season the continental climatic influence is dominant and therefore, overall, Finland remains relatively dry.

3.2.3 CLIMATE OF ONTARIO

Ontario, having a total surface area of 1.07 million km^2, has a wide range of climates which differ significantly from the shores of Hudson Bay in the north, to Point Pelee in the south. More specifically, the climate of Ontario can be subdivided into three distinct classifications along a north-south axis. According to the system of climatic classification as developed by D.F. Putnam (1952), the climate of Hudson Bay Lowlands region is referred to as Boreal East Coast whereas the remainder of Northern Ontario is classified as Cool Continental Cool Summer. The climate of Southern Ontario is characteristic of Cool Continental Warm Summer.

The principal reasons for the varied climate in Ontario are:

- Ontario lies in the path of the westerly winds,
- the presence of Polar air masses and Hudson Bay to the north of Ontario,
- the proximity of a sizable portion of Ontario to the Great Lakes, and
- Ontario's location on the North American continent.

Differences in relief may also contribute, to a lesser degree, to local variations in climate.

As a result of these influences, summer climate conditions in Northern Ontario are characterized by a pattern of two or three days of fine weather followed by warmer more humid weather, often with changeable winds and rain for a day or two. While the relative durations of fine and stormy weather spells vary, this pattern of weather sequence is repeated many times each year in Northern Ontario, as a continuing succession of cyclonic storms, created by warm humid air masses from the south, alternating with cooler and drier air from the north, sweep over the area (Chapman *et al.*1968).

Similarly, Southern Ontario is subject to the same climatic conditions, however, summers do tend to be warmer and more humid. It is important to note that Southern Ontario's climate can differ significantly from one location to another due to topography, the proximity of the Great Lakes and the prevailing winds (Brown, 1968).

3.2.4 COMPARISON OF THE CLIMATES OF ONTARIO AND FINLAND

For the purposes of comparing Ontario's climate to that of peat producing regions of Finland, 11 weather stations within Ontario were selected. On the basis of proximity to peat deposits and major transportation routes and with the intention of developing a reasonable representative overview of the climate of the Province, the following locations within Ontario were considered:

- Peterborough
- Kemptville
- Sudbury
- New Liskeard
- Kapuskasing
- Nakina
- Atikokan
- Fort Frances
- Red Lake
- Lansdowne House
- Moosonee

The Finnish cities selected were:

- Jokioinen
- Ahtari
- Tohmajarvi
- Haapavesi
- Rovaniemi

Plate 3-1 shows the location of the above stations and the relative positions of Ontario and Finland on the earth in terms of latitude. Chatham, New Brunswick data is included mainly for interest, since that area of New Brunswick produces substantial quantities of horticultural peat. The comparison has been restricted to the period start of May until the end of September, since this corresponds to the peat harvesting or mining season.

In this analysis, 7 parameters for which data was most readily available were compared: precipitation, temperature, hours of bright sunshine, wind, the frost-free period, the mean annual potential evapotranspiration and the mean annual moisture deficit.

3.2.4.1 PRECIPITATION

Plate 3-2 shows that the selected 11 Ontario stations receive 40% more precipitation on average than do the Finnish stations during the period from May to the end of September. The distribution of precipitation is for the most part evenly distributed in Finland, but in Ontario this is not the case. Moving north from Peterborough to Kapuskasing, precipitation apparently increases then decreases at Nakina and further north (Lansdowne House, Moosonee). Areas in western Ontario show highest rainfall of the stations studied, whereas Red Lake to the northwest was low and similar to Sudbury regarding the amount of precipitation during the period May to September inclusive.

Along with the amount of precipitation received at each station, its distribution during the period from May to September is also important. Although Atikokan receives 487 mm of precipitation during the time period in question, a check of the frequency of dry and wet periods (Plates 3-3 and 3-4) shows that periods of 3 or more consecutive dry days (but less than 7) occur approximately 3 times a month in the same time period (data for Atikokan was taken from Kakabeka Falls) while Plate 3-3 also shows that one of the 3 or more consecutive dry periods will be of 7 or more days (but less than 14); periods of 3 or more consecutive wet days (but less than 5) occur approximately once a month in each of the months during the peat production season. This observation holds true for most of the Ontario stations (for which data of this nature was available) except for Kapuskasing and Lansdowne House. It appears that summer precipitation is not evenly distributed but of a frontal nature, with periods of dry days interspersed with lesser periods of relatively heavy rainfall. With reference to Chatham, New Brunswick, the precipitation pattern is found to be very much similar to that of Ontario in that the precipitation is highly influenced by weather systems passing through the area.

The implications, based on rainfall data, are that although total rainfall in certain areas of the Province is generally more than in Finland, there are dry periods of sufficient duration to allow peat mining activities to be carried out. Sod peat production may be preferred in areas with greater precipitation since sod peat mining is generally impeded to a lesser degree by rainfall.

3.2.4.2 SUNSHINE

Plate 3-2 shows the distribution of bright sunshine hours to be relatively uniform over the period May to September inclusive with a wider variation in the Ontario data. Most Ontario stations received slightly more hours of sunshine (with the exception of Kapuskasing, Moosonee, Nakina, and New Liskeard) than the Finnish stations, however, for the stations studied the averages for Finland and Ontario were the same. However, it should be noted that Finland, occupying a more northerly position receives sunlight of a lower intensity than Ontario. Also, it was noted that hours of

PLATE 3-1. LOCATION OF WEATHER STATIONS IN ONTARIO.

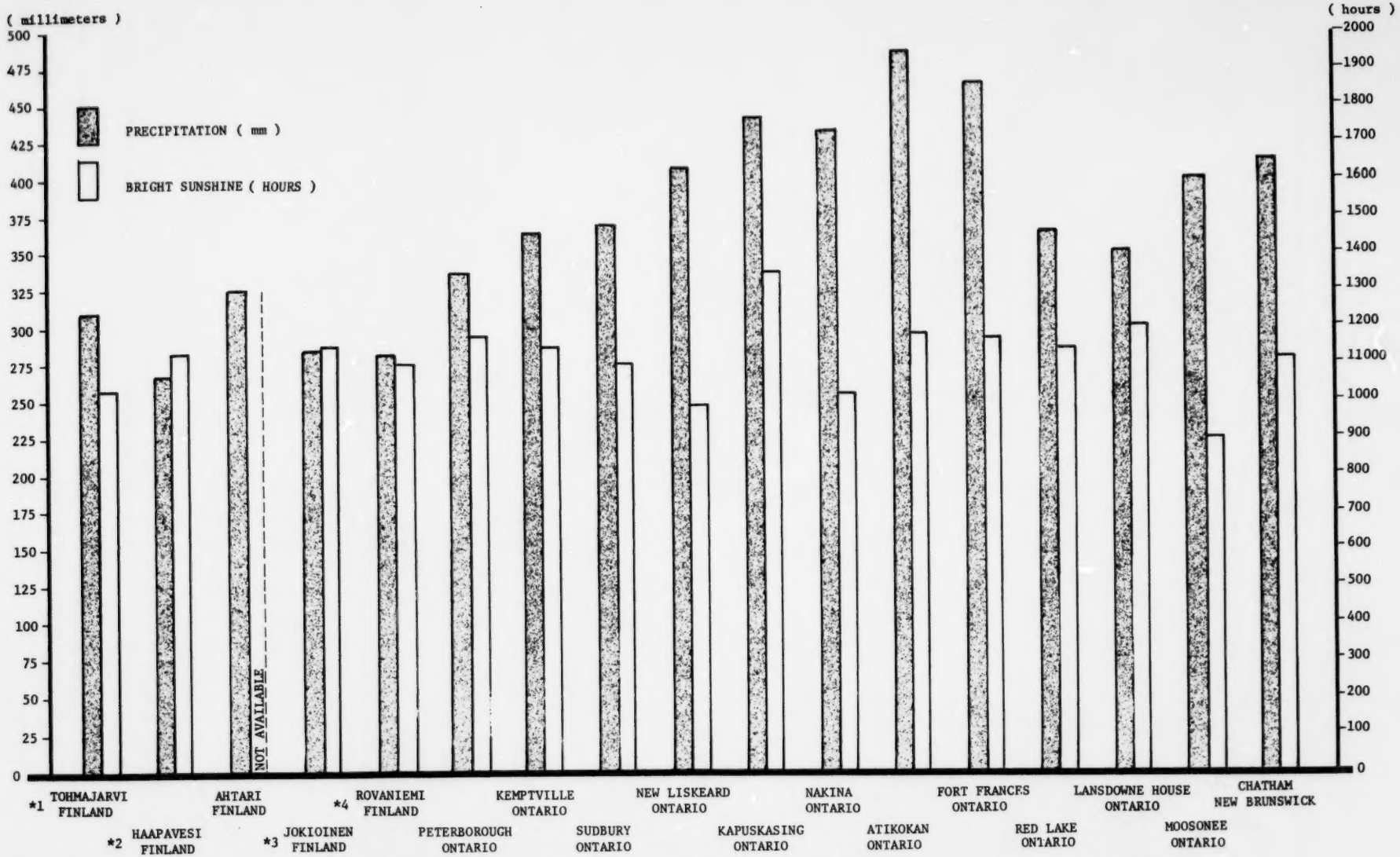


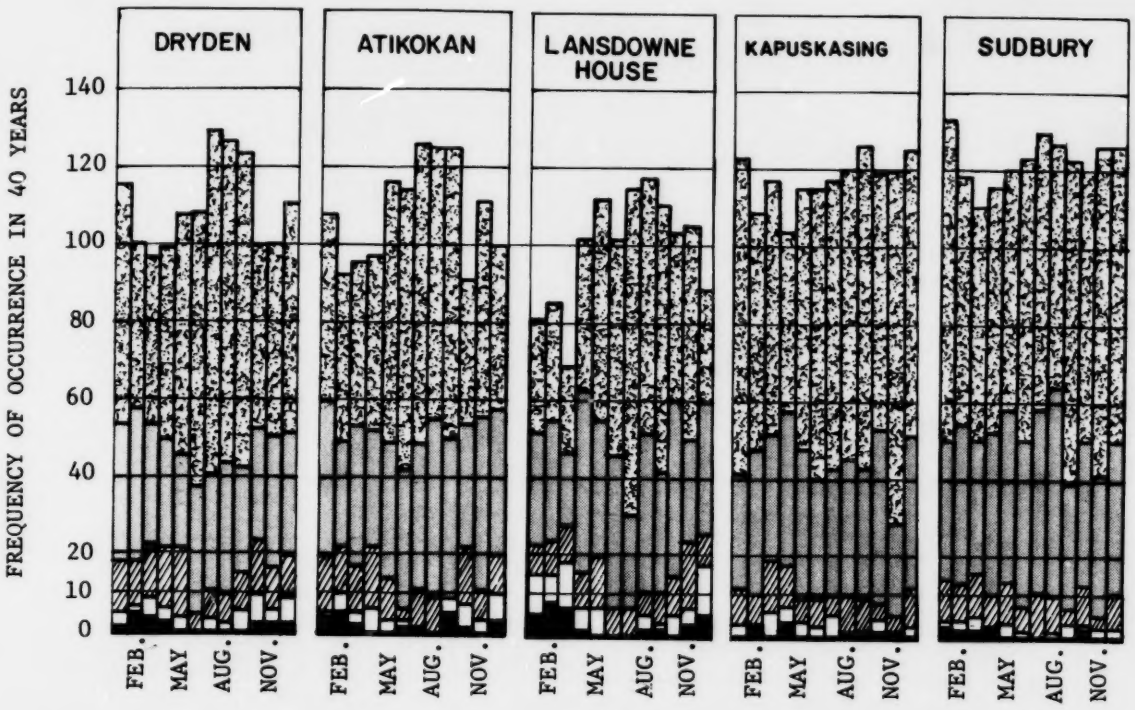
PLATE 3-2. PRECIPITATION AND BRIGHT SUNSHINE HOURS.

*FOR BRIGHT SUNSHINE HOURS, NEARBY ALTERNATIVE STATIONS WERE SELECTED.
NOTE: PERIOD MAY TO SEPTEMBER INCLUSIVE.

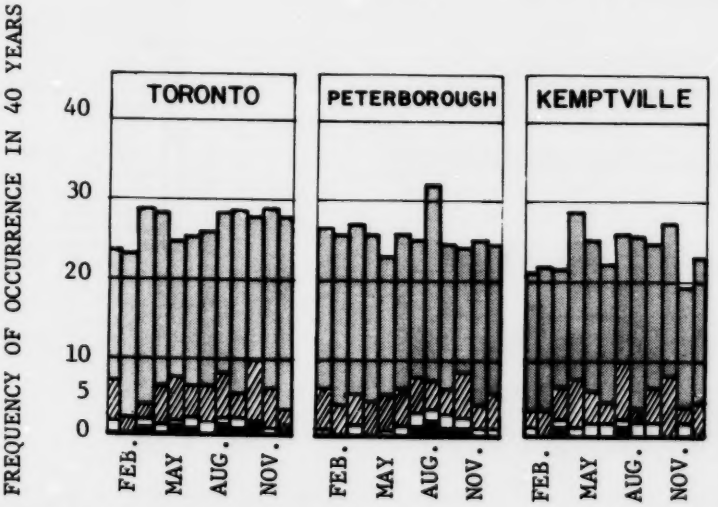
bright sunshine increase when proceeding from Moosonee through Nakina and Atikokan to Fort Frances or when moving south from Moosonee through Kapuskasing, and New Liskeard to Peterborough. The number of hours of bright sunshine at Chatham, New Brunswick was determined to lie near the average of the number of hours of bright sunshine received by both Ontario and the Finnish stations.

3.2.4.3 TEMPERATURE

The average mean daily temperatures for the months May through September are shown in Plate 3-5. The Ontario stations studied experienced a higher average mean daily temperature (about 18%) than stations in Finland, except for the most northerly stations (Nakina, Lansdowne House and Moosonee), the mean of which was still higher than the mean of the Finnish stations. Chatham, New Brunswick was found to be similar to the temperature of the Ontario stations.



NOTE SOURCE: CHAPMAN AND THOMAS, BROWN
*DATA FOR PETERBOROUGH TAKEN FROM LINDSAY
**DATA FOR KEMPTVILLE TAKEN FROM OTTAWA
***DATA FOR ATIKOKAN TAKEN FROM KAKABEKA FALLS
****DATA FOR SUDBURY TAKEN FROM CONISTON



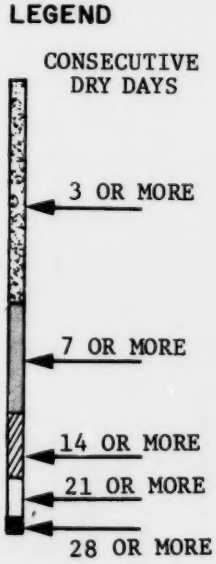


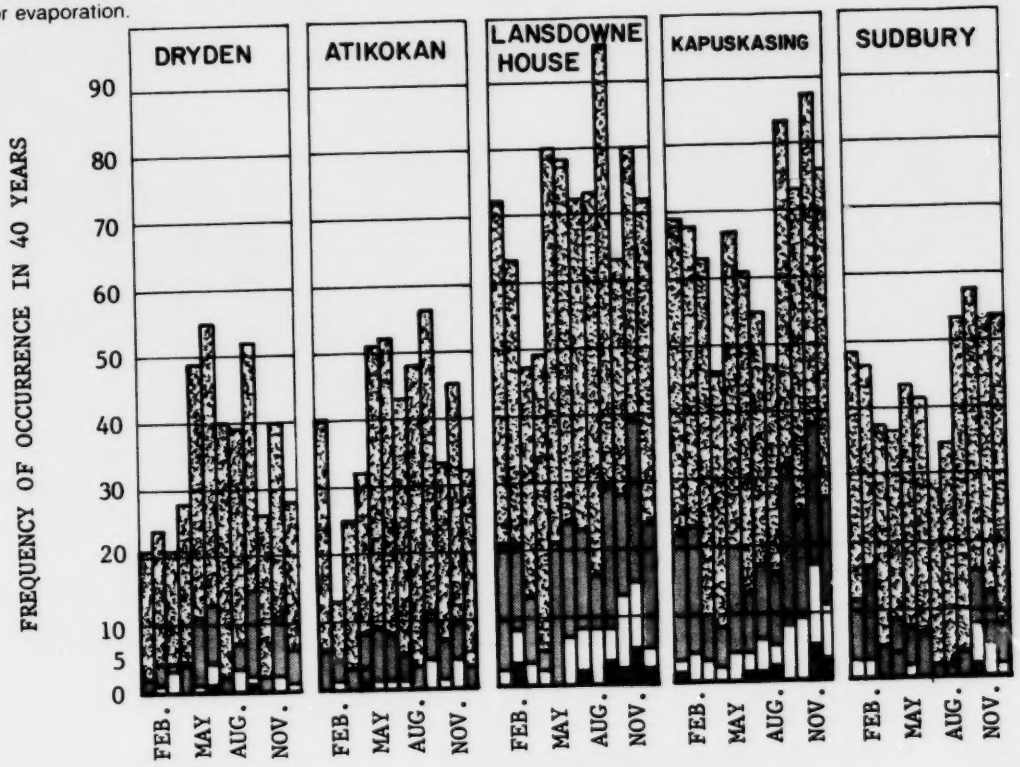
PLATE 3-3. CONSECUTIVE DRY DAYS.

3.2.4.4 WIND

As can be seen in Plate 3-5, the Finnish stations experience higher force winds than the stations in Ontario or Chatham, New Brunswick. On average, the winds in Finland are 50% greater, based on wind speed, than those in Ontario (Chatham, New Brunswick is quite similar to Ontario stations). Although the winds in Ontario are not of the same force as those prevailing in Finland, the frequency of occurrence of calm winds is relatively low (5 to 10% over most of the province). Moderate steady winds prevail and are favourable for evaporation.

3.2.4.5 FROST-FREE PERIOD

The duration of the frost-free period is an indication of the length of the peat production season, provided other climatic parameters are favourable. Usually, anywhere from two to four weeks of bog drainage are required following the last spring frost before milled peat production can begin, while production terminates with the first fall frost.



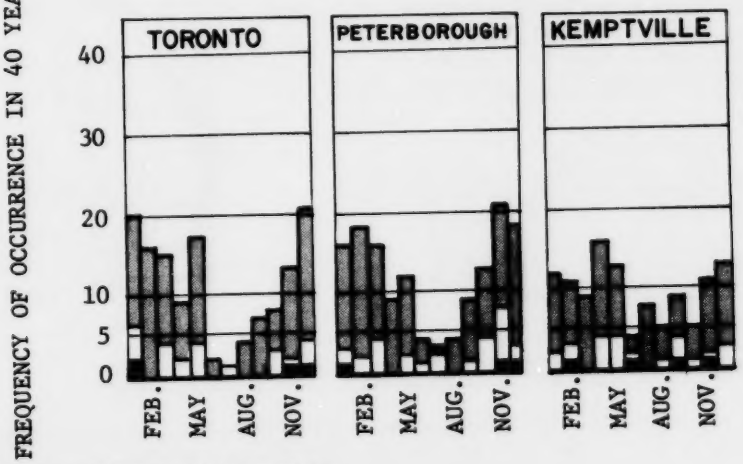
NOTES SOURCE: CHAPMAN AND THOMAS, BROWN

*DATA FOR PETERBOROUGH TAKEN FROM LINDSAY

**DATA FOR KEMPTVILLE TAKEN FROM OTTAWA

***DATA FOR ATIKOKAN TAKEN FROM KAKABEKA FALLS

****DATA FOR SUDBURY TAKEN FROM CONISTON



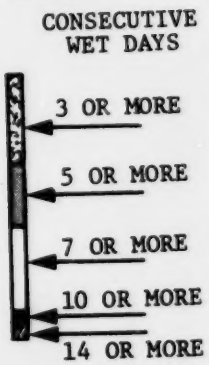
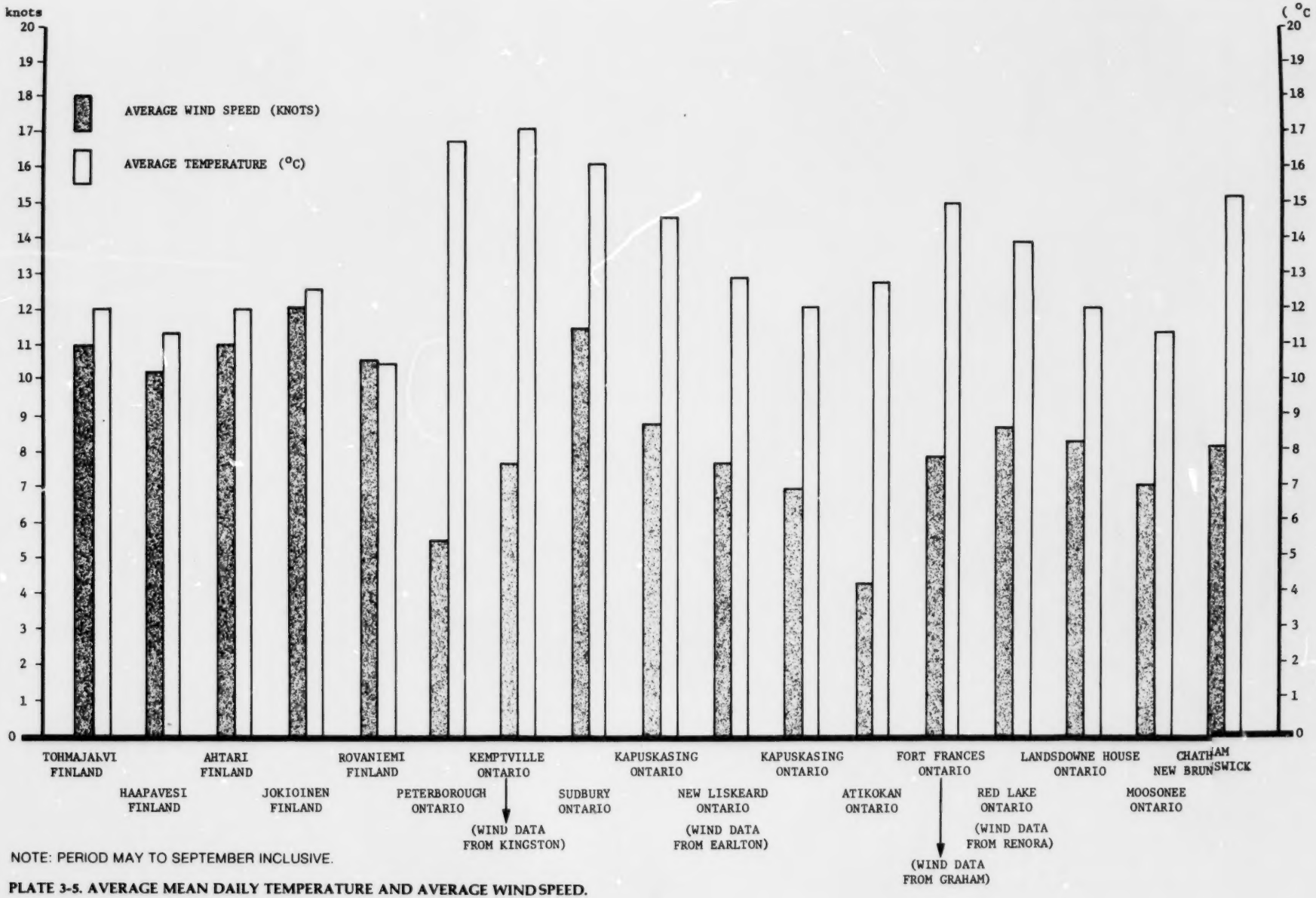


PLATE 3-4. CONSECUTIVE WET DAYS.



NOTE: PERIOD MAY TO SEPTEMBER INCLUSIVE.

PLATE 3-5. AVERAGE MEAN DAILY TEMPERATURE AND AVERAGE WIND SPEED.

Although Southern Ontario, as expected, has the longest frost-free periods, it is interesting to note that Fort Frances, Red Lake and Lansdowne House have lengthy frost-free periods similar to Chatham, New Brunswick (see Table 3-2). Finnish data was not on a comparable basis and could not be included.

3.2.4.6 POTENTIAL EVAPOTRANSPIRATION

Potential evapotranspiration as used in this comparison is according to C.W. Thornthwaite's water balance model, and is defined as the amount of water that would be evaporated or transpired from a surface completely covered with vegetation if there was sufficient water in the soil at all times for the use of the vegetation. Potential evapotranspiration, expressed in the same units as precipitation, is an index of both thermal efficiency and the water need for growth (Phillips, 1976).

TABLE 3-2. "FROST-FREE PERIOD" DATA*.

STATION	START	END	DURATION (Days)
Peterborough	May 11	September 29	140
Kemptville	May 16	September 23	129
Sudbury	May 12	September 30	140
New Liskeard	June 14	September 8	95
Kapuskasing	June 13	September 5	83
Nakina	June 14	August 29	75
Atikokan	June 16	August 28	72
Fort Frances	May 25	September 19	116
Red Lake	May 31	September 23	114
Lansdowne House	June 2	September 23	112
Moosonee	June 21	September 1	71
Chatham, N.B.	May 22	September 21	122

*Frost Data—Environment Canada

Potential evapotranspiration can be considered a variable of significance related to the mining of peat inasmuch as it is a function of the climate of the location (Phillips *et al.* 1981). As expected, Plate 3-6 shows the mean annual potential evapotranspiration to be greater in Southern Ontario than in Northern Ontario due to the difference in the "energy loading" of the two areas and as a result of this, the lines of equal potential evapotranspiration decrease as one proceeds northward. A line joining Timmins, Thunder Bay and Red Lake corresponds approximately to the southern most parts of Finland and both decrease northward (Hare, 1955).

3.2.4.7 MOISTURE DEFICIENCY

According to C.W. Thornthwaite, moisture deficiency is the amount by which the available moisture fails to meet the demand for water (Phillips, 1976). Plate 3-7 shows that the mean annual moisture deficiency in Ontario is similar to that of Finland. Fort Frances has nearly an identical moisture deficiency to large parts of Finland. With respect to moisture deficiency, Chatham, New Brunswick is similar to areas in Southeastern Ontario.

Although no statement can directly be made on peat mining in reference to moisture deficiency, it can however be used as an indicator of dryness inasmuch as moisture deficiency reflects the amount of moisture that is drawn from soil to meet various evaporation and vegetal requirements imposed by the "energy loading" on the area.

3.2.5 SUMMARY OF CLIMATIC FACTORS

The following observations were noted from a brief analysis of climate:

- On the basis of trends and similarities in temperature, hours of bright sunshine, mean annual potential evapotranspiration, and moisture deficiency, the climate of Northern Ontario is shown to be similar to that of Finland.
- Dr. F.K. Hare has further suggested that from the standpoint of moisture balance and thermal efficiency (based on a vegetation analysis), a close parallel clearly exists between the climates of Finland and that of eastern Canada. Specifically, Finland occupies a position similar to the belt stretching from the Lake Timiskaming district to a point close to the Hudson Bay shore in Northern Ontario (Hare, 1955).
- Due to the fact that parts of Northern Ontario are shown to be similar to Finland with respect to climate, it is expected that peat production yields will be similar to that achieved in Finland, and similar methods can be employed. Areas shown to experience somewhat higher rainfall, such as Thunder Bay—Rainy River region may be more suitable to a sod peat mining system. However, it is recommended a more detailed analysis of local climate be carried out prior to final selection of peat mining systems for a particular area.
- Although in general, frontal precipitation during the summer season is higher in most parts of Ontario than in Finland, generally higher temperatures and more sunshine hours prevail in Ontario and the annual potential evapotranspiration is much higher than in Finland. Chatham, New Brunswick, an experienced horticultural peat producing region of Canada has climate characteristics similar to Sudbury and to a lesser extent, Fort Frances.
- For purposes of performing a very approximate ranking in terms of peat production potential for the 11 areas of Ontario studied, the various climatic factors such as least rainfall, most sunshine hours, highest temperatures, longest frost-free period (all for the May to September period), highest amount of annual evapotranspiration and highest amount of annual moisture deficiency were considered on an equal basis as a measure of the suitability of areas for the production by conventional dry mining techniques (all fuel peat production in the world is currently by dry mining techniques).
- The preliminary analysis showed Southern Ontario to be most favourable, followed by Sudbury and the Rainy Lake–Kenora–Red Lake region, with about equal potential. Lansdowne House was the next most suitable area, even though it was the most northerly weather station considered, next were the New Liskeard and Atikokan areas, followed by Kapuskasing, Nakina and Moosonee in that order. Chatham, New Brunswick in the analysis was found to be similar to Sudbury and Rainy Lake–Kenora–Red Lake. The preliminary ranking was developed as a basis for estimating the effect on peat production rates, hence peat mining costs. In general, most of the areas of Finland, ranked on the same basis, were shown to be similar to Red Lake and Lansdowne House.

As a result of the preliminary climatic investigation, it is recommended that for the next phase of peat development in Ontario, a detailed climatic analysis be carried out for the various regions of Ontario with peat development potential so that a better understanding of the microclimates can be attained. For instance, it may be possible to identify the ideal climatic parameters for peat mining and consequently determine through computer based data analyses how often and when such favourable conditions would occur in any given area of the Province.

PLATE 3-6. MEAN ANNUAL POTENTIAL EVAPOTRANSPIRATION.

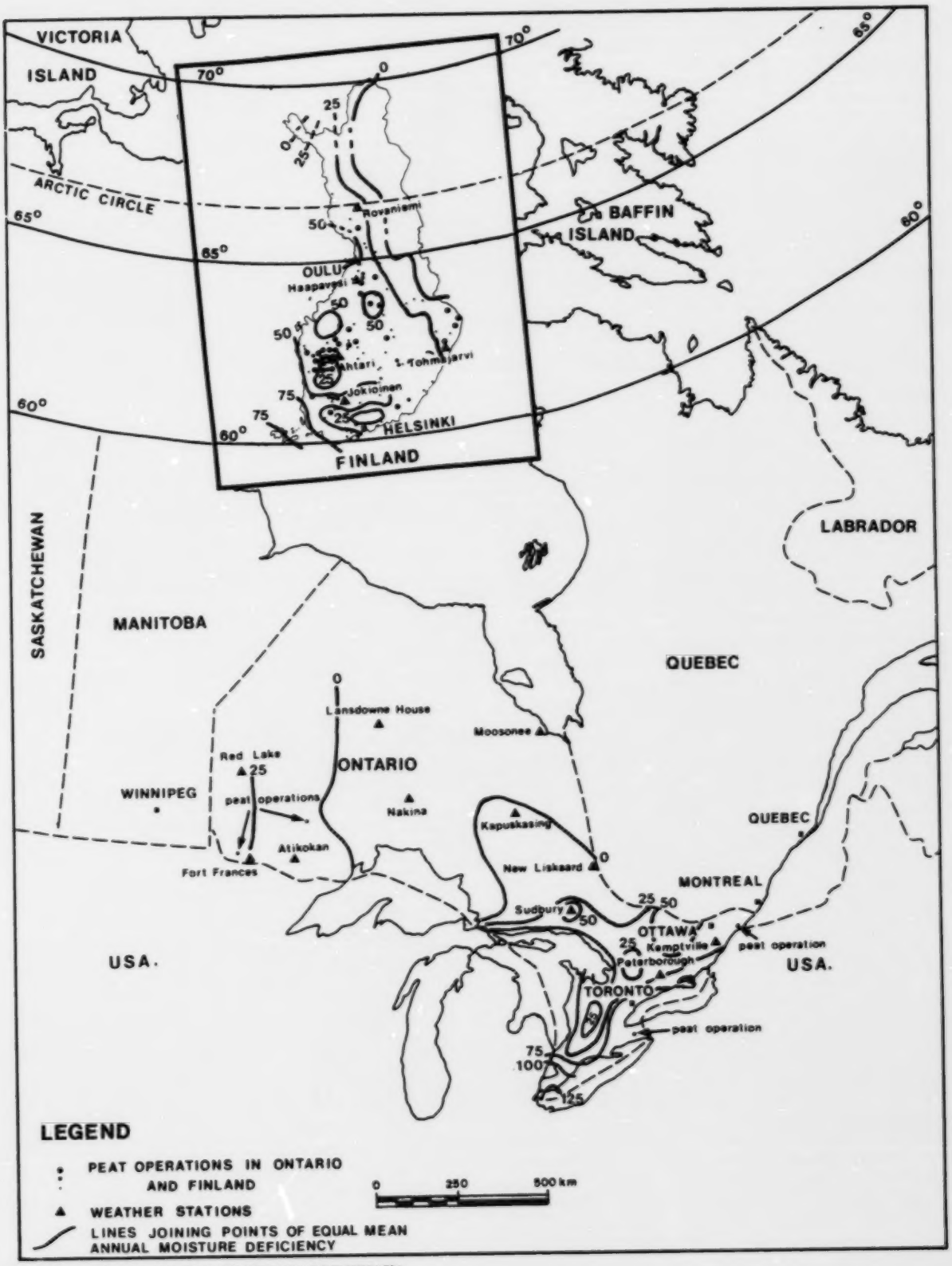


PLATE 3-7. MEAN ANNUAL MOISTURE DEFICIENCY.

3.3 MARKET CONSIDERATIONS

Depending on the location of the peatland, the type of peat it contains and other factors, it can be used for a number of purposes such as agriculture, as a source of horticultural peat, for forestry, for industrial purposes as a fuel, as a feedstock for producing coke and activated carbon, or a chemical feedstock for resins and waxes, and other processes. In recent years peat moss has become a widely used commodity, not only in countries where it is found, but also countries with warmer climates, such as Israel and some African nations, to provide suitable replenishment of organic matter for agricultural purposes. Recently, the shortage of fossil fuels has aroused an increased interest in peat as an alternative source of fuel, not only in Europe where it has been utilized for many years, but also in North America.

As it is possible to produce many different peat products, each having a different market value and thus different market transportation limits, a detailed assessment of peat markets becomes an important step in planning a peatland development. To illustrate this point, several popular peat products are listed in Table 3-3, along with their approximate market value and economic limit of distance of transportation to market. Table 3-3 is based on published data from Finland and other information available from horticultural peat operations in eastern Canada.

It is common in Europe to have several peat products produced from the same bog operation. For example, a peat operation may produce horticultural peat from the less humified areas (or adjacent peatlands), supply milled fuel peat to a power station and/or a briquet plant, and possibly produce sods from an area of more humified peat layers.

In Ontario, it is expected that similar markets, as described above and more fully analysed for specific case studies in Part 5, exist to varying degrees and it will be necessary to carry out detailed market analyses before large-scale peat developments can be implemented.

TABLE 3-3. APPROXIMATE MARKET VALUE OF PEAT AND ECONOMIC LIMIT OF TRANSPORTATION.

Peat Product	Wholesale Market Value per Tonne	Economic Limit of Transportation (by Road or Rail)
Bagged Horticultural Peat	$140.00	2,000 km
Milled Fuel Peat	30.00	100 km
Sod Fuel Peat	45.00	200 km
Briquet Fuel Peat	90.00	400 km
Peat Pots	200.00	3,000 km

3.4 RESOURCE ASSESSMENT

3.4.1 GENERAL

Peatlands constitute a natural resource with potential for a large variety of uses. For proper planning, this resource, like any other resource, should be properly surveyed and an inventory of the deposits including their characteristics should be made. Depending on the location of a peatland area and on the type of peat it contains, it can be used for a number of purposes as described earlier in this Part.

As discussed in Part 2 of this study, there are at least 4 main classifications of peat and a range in degree of humification from live moss to 12,000 year old highly humified peat. The bulk density of peat can vary 5 fold and the heat value 65% on a dry basis. With such a wide range in the physical, chemical and thermal characteristics of peat, it is clear that the peat resources must be matched with the product to be marketed. Specialized peat sampling techniques and standards for analysis have been developed to make resource classification as consistent as possible.

Data from the field analyses and measurements and peat quality assessment are used to prepare maps and cross-sections as required for the resource assessment work. Maps are used to display the different cover types, isopachs of peat depth at suitable contour intervals, surface contours, and other maps as required to illustrate the survey network and sample points, drainage features, bottom contours, etc. Cross-sections are prepared which show the variation of humification and peat type with depth. Resource calculations can then be performed according to the breakout of information desired.

3.4.2 DETAILED SITE SURVEY

Once the bog selection criteria have been satisfied and a development area has been outlined, it is then necessary to carry out a detailed field bog survey (Level 4) as outlined in Part 2, to form a basis for the actual mine planning. The first step in the bog survey is to construct a grid on the bog using aerial photographs to select a main axis of the bog and cross-lines at suitable intervals. At the end of the lines and at intersections of the main line and the secondary lines, stakes are driven into the peat. The surface elevations along the total line system are then measured for level control.

The surface characteristics and the vertical peat profile is studied at suitable locations using the modified von Post system and recorded. The sampling intervals can vary from 100 m to 200 m depending on the homogeneity and size of the deposit. Near the edge of the deposit, peat depth is recorded more frequently than elsewhere until a cut-off depth of about 1 m is reached. This facilitates later calculations of volumes and quantities for mine planning purposes.

For a detailed survey, a map scale of 1:10,000 is in most cases suitable. The map showing the extent of the peat deposit can also show the location of the survey lines and the sampling sites. A typical example is illustrated on Plate 3-8.

3.5 MINE PLANNING AND OPERATIONS

3.5.1 SELECTION OF A SUITABLE BOG

The principle criteria for the selection of a bog for development within any particular region of the Province are:

- quantity and quality of resource,
- proximity to market,
- drainability,
- peat thickness,
- land ownership, and
- other considerations such as mining method and environmental considerations.

Other criteria, such as a minimum bog size are also important, however, they tend to be more site specific and market oriented and are not covered here.

3.5.1.1 QUALITY OF RESOURCE

Peat quality determines the suitability of a deposit for horticultural or energy development, and also is an important aspect in the determination of the most suitable mining method. For example, while sod peat production may be the most desirable mining method from a product marketing point of view, it is possible that the peat may be of the type that will not sod. Certain peats which are near the higher end on the degree of humification scale, are not fibrous

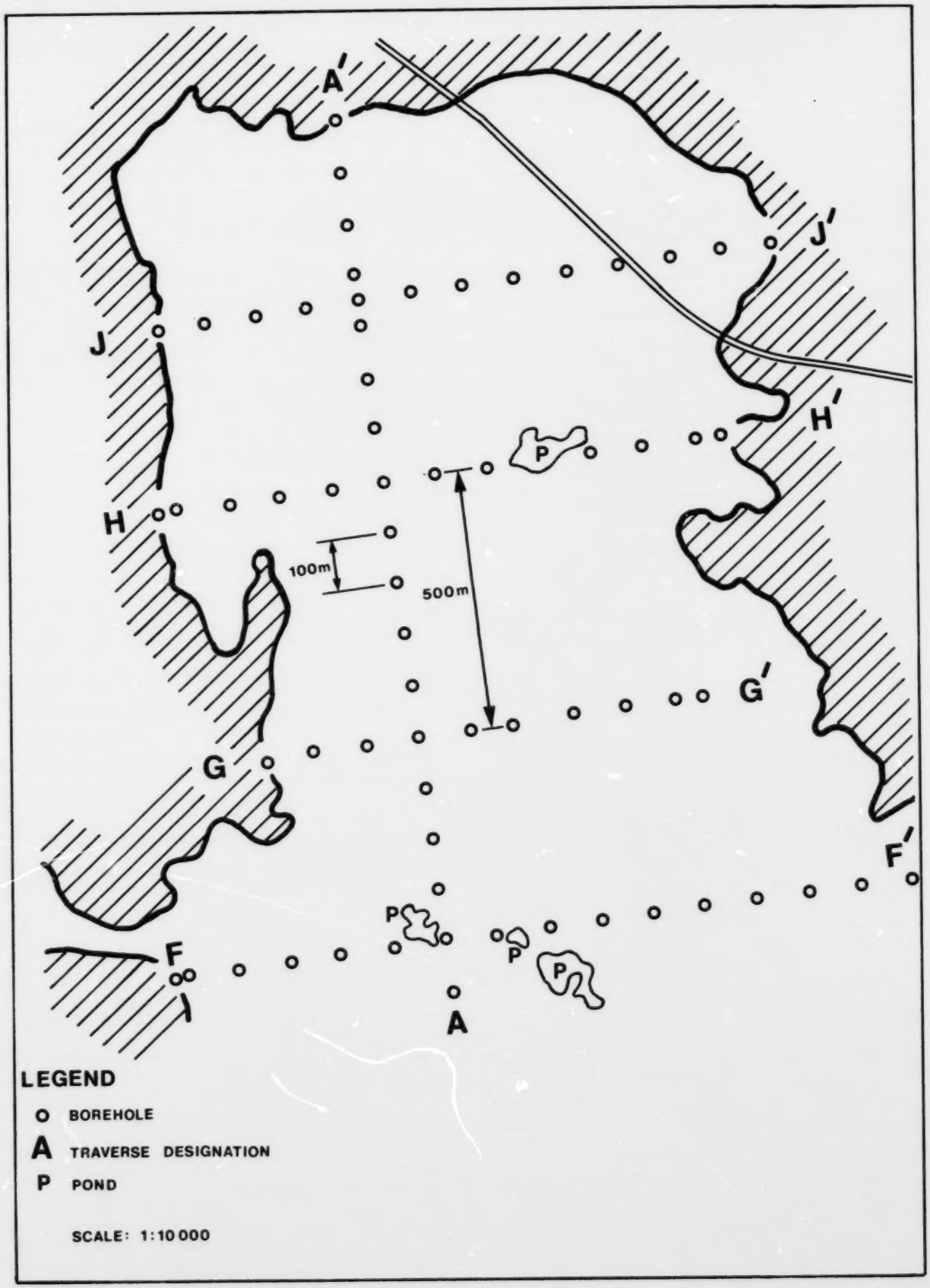


PLATE 3-8. TYPICAL BOG SURVEY PLAN.

enough to form sods and can only be mined by the milled peat production method. Selective mining can also be done to blend different peat qualities, to ensure a more uniform end product.

The best quality horticultural peat will have an absorptive value of 5 times its own weight and a bulk density of less than 100 g/ℓ at 50% moisture. Good quality fuel peats generally have a calorific value of 5,300 kcal/kg (9,500 Btu/lb) and less than 5% ash on a dry basis.

3.5.1.2 PROXIMITY TO MARKET

Due to the relatively low bulk density of both horticultural and fuel peats, it is a costly commodity to transport. Horticultural grade peat, compressed into 6 cu ft (170 ℓ) bales at a 2:1 ratio, can withstand greater transportation distances due to the higher market value of the product. Fuel peat must compete with the cost of alternate fuels, while there is no immediate substitute for horticultural peat. Studies have shown that the cost of fuel peat approximately doubles every 150 km it is transported by road or rail and that the most economic fuel peat utilization scenarios are at bogside.

3.5.1.3 DRAINABILITY

Drainability is a key factor in determining whether a bog can be taken into production or not. In the case of conventional dry mining methods, a bog that cannot be drained cannot be put into production. The aim is to drain only as much of the bog as is required to enable the surface to carry mining equipment, and to ensure that enough of the bog is drained outside the mining areas to form a stable base for possible storage piles, and haul roads.

A bog should have a definite slope (while it may be slight) and should be located at the upper end of the local watershed to ensure that the relative elevation of the bottom of the bog is higher than the surrounding streams and ponds.

3.5.1.4 MINE LIFE

The basic outline of the area to be mined is determined by the thickness of the deposit. It is common practice to avoid mining areas of the deposit less than one metre in thickness. The main reasons are the possibility of interference of the uneven mineral soil base with the mining equipment, the increase in ash content or a chance of mineral soil contamination in the shallow basal peats, and unsuitability of thin young peat layers for fuel purposes because of their low degree of humification and large quantities of roots and other woody material present.

In the case of the milled peat methods, it is possible to mine deposits less than one metre in thickness if the peat is suitable, since the milling equipment removes only about 1-2 cm layers of peat. However, when using sod cutting equipment, it is advisable to avoid thin deposits since the sod cutter penetrates about 80 cm into the peat when fully extended, and runs the risk of damage on occasional boulders or rock subcrops hidden in the basal peat.

Generally, bogs having an average depth of 2.5 m contain sufficient peat to support conventional peat production methods over an economic life of about 25 years. Many deeper deposits in Ireland have been in operation for over 50 years.

3.5.1.5 LAND OWNERSHIP

This aspect of mine planning is self-evident; to use the resource it must be controlled in some manner. For Crown Lands, after having carried out the required development, a lease is usually granted. If another private party owns the property of interest, other arrangements may have to be made such as purchase, rental, or royalty on production.

3.5.2 DRAINAGE PLAN

In the case of the dry mining methods, the most conspicuous and important feature in mine planning is the drainage plan, which has to suit both the environment and the mining system considered most suitable for the location and for the desired peat production. Consideration has to be given to the size and layout of fields and includes the orientation of all field ditches, bog roads and field storage piles. The outline of the area with peat thickness of 1 m or more, the general shape and slope of the bog, length of fields, the location of access roads and consequently the most suitable location of stockpiles and service facilities, all influence the final mine plan.

Production fields can be spaced at varying intervals. In eastern Canada, the horticultural peat producers have commonly used 100-150 feet spacing (30-45 m). This is often adequate on well drained, raised bogs with high domed centers and highly permeable, slightly humified sphagnum peat. In Europe, the customary ditch spacing is 10-20 m. A 10 m spacing, in most cases, provides an unnecessary dense ditch pattern. Only in areas with high precipitation, very highly humified peat, and very flat topography can it be justified. The close ditch spacing adds to the preparation and maintenance costs, increases the loss of usable peat area and can create problems with the operation of heavy equipment. A 20 m spacing is most common and is suggested for Ontario conditions.

A typical conceptual mine plan is included (Plate 3-9) to illustrate the configuration of production fields, bog haul roads, peat storage piles, and ancillary facilities for a typical milled peat mining operation. This conceptual layout is sized for about a 100,000 tonne per year peat operation (50% moisture).

3.5.3 BOG PREPARATION ACTIVITIES

3.5.3.1 PERIMETER DITCHING

Properly designed perimeter drainage ditches and careful ditch maintenance are the key factors in preparation for a successful milled peat operation. A virgin bog will average about 95% moisture content *in situ*, varying from 97% at surface to 92% at depth. Primary ditches are cut during the first year of bog development to drain off existing ponds, to isolate the bog drainage ditches at the bog limits from the surrounding terrain and to accelerate the drainage rate of the spring melt waters during the pre-production stage.

A specially designed low ground pressure excavator or ditcher is usually used to carry out this work (see Plate 3-10). Such equipment is capable of cutting a slot or V type ditch 1 m to 2 m deep by 1 m to 2 m in width at a rate of about 100 m/h. This type of ditcher is very suitable because of its low capital and operating cost, high manoeuverability, its versatility, and because it can cut and maintain both primary and secondary ditches. The use of conventional ditching equipment has also been found to be acceptable in some operations.

A 2,000 ha bog will require approximately 19 km of perimeter ditches and 26 km of cross-bog ditches at 400 m centers. The spacing of cross-bog ditches is determined by the production capacity of the principal mining equipment such as a vacuum machine.

Perimeter ditching should be completed in the first year of bog development and as ditches tend to close up rapid-

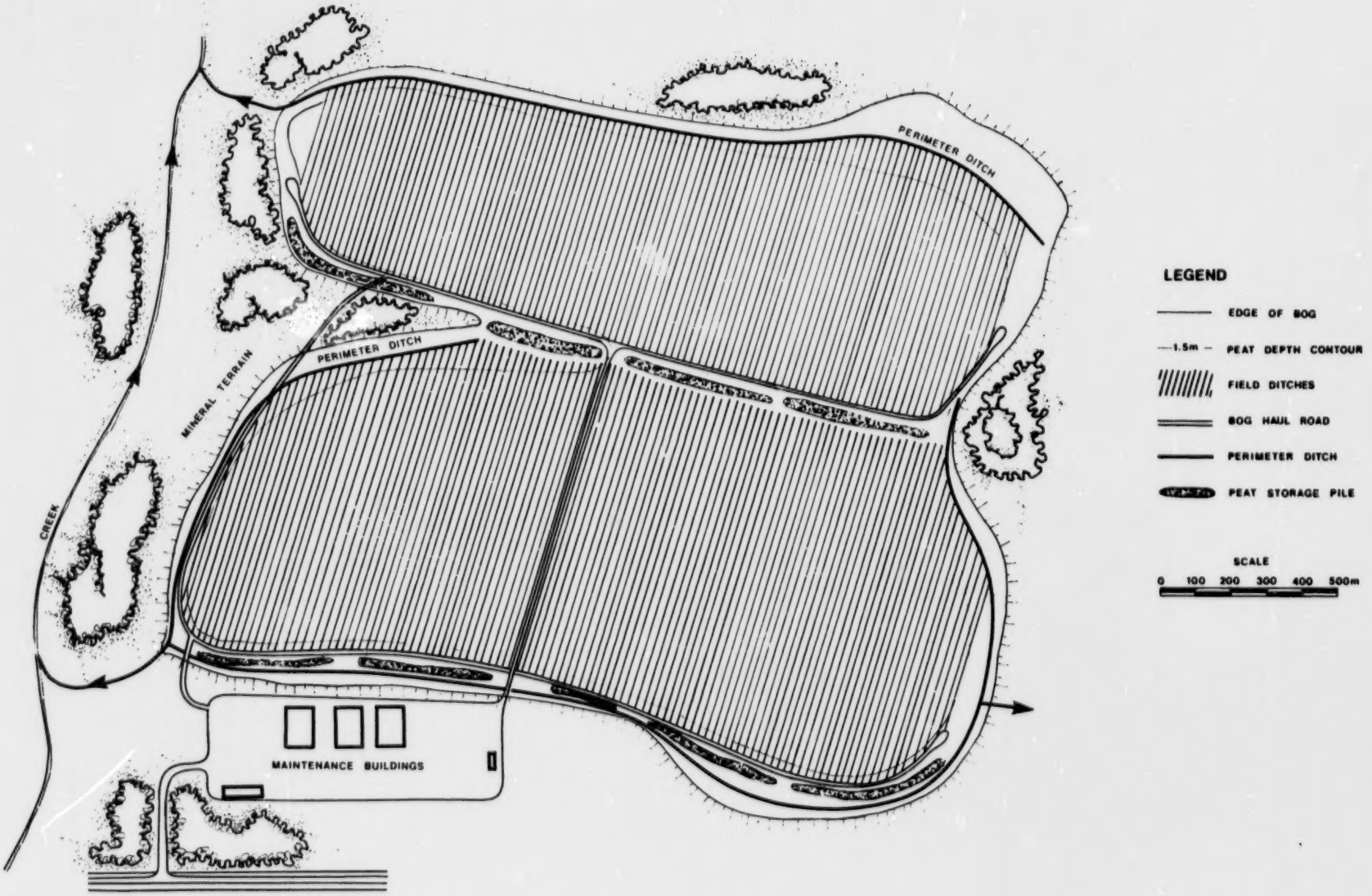


PLATE 3-9. CONCEPTUAL MILLED PEAT MINE PLAN.

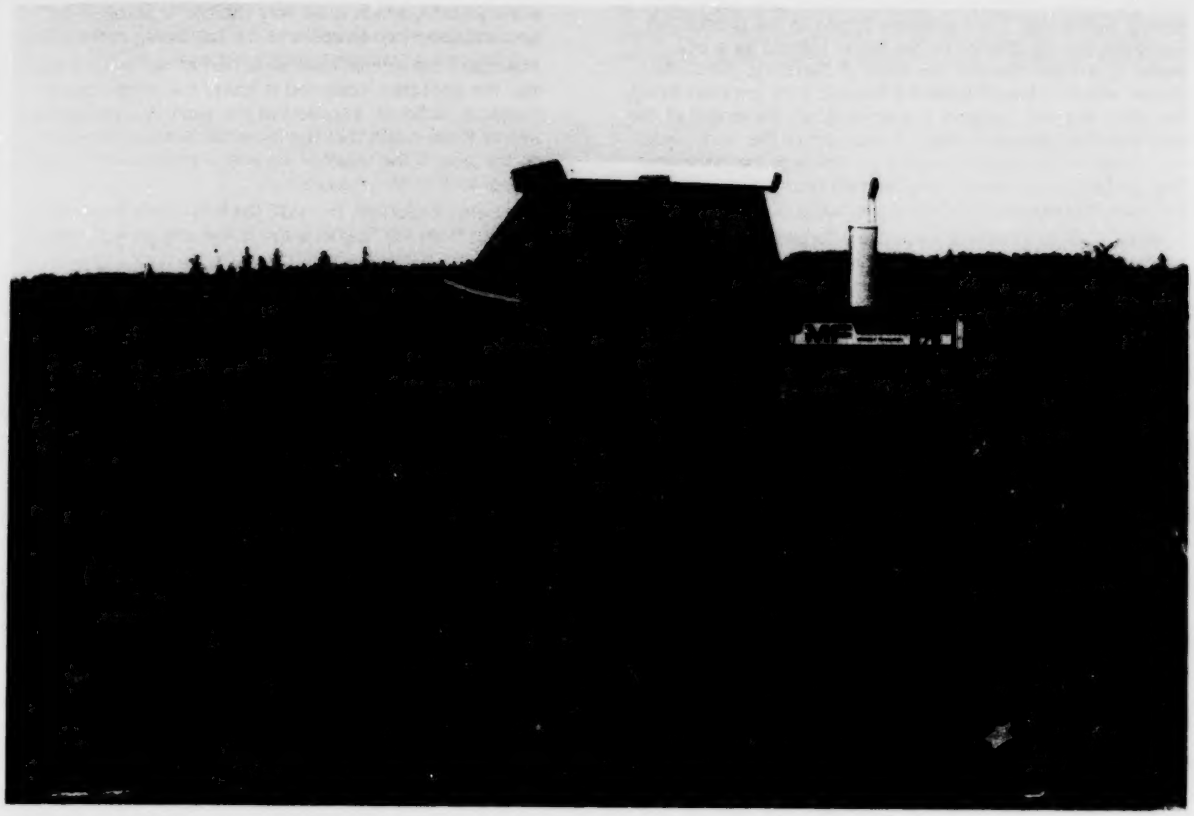


PLATE 3-10. BOG DITCHING MACHINE.

ly, at least two cuts over the same ditch should be planned during the pre-production phase. The advance rate of the ditcher will complete the 2,000 ha task in 100 days. The cross-bog primary ditches should be planned at 45° to the drainage pattern and will achieve the maximum gravitational drainage possible.

3.5.3.2 SURFACE CLEARING

Bog surface clearing involves the removal of all trees, shrubs, and live moss from the bog. Generally speaking, the more humified the peat in-place the more surface growth of shrubs and trees will occur. For example, those deposits having an open moss center will usually be overlain with sphagnum peat whereas areas around the periphery will have surface growth of shrubs and trees over more humified peat. Peat producers who have cleared surface growth indicate that on average it costs about $2,500/ha ($1,000/acre) to cut and remove the tree growth, assuming about 20% coverage. In cases where a substantial forest must be removed, the value of the commercial grade timber may offset the cost of clearing the land.

After the tree and shrub growth has been stripped, the surface moss should be chopped and rotovated into the upper peat layer. Any buried stumps must be removed and the fields must be graded between field centers and ditched to provide drainage. For this, a slope of 20:1 is normal. Finnish practice is to remove stumps by a specialized tracked vehicle which cuts the roots out of the surface and piles them for removal. While stump removal may not be a significant factor in a number of Ontario peat deposits, it may be necessary in some sections of some bogs. A stump removing machine costs approximately $220,000 and has the capacity to work to 0.45 m depth, and can clear roots at a rate or 0.4 ha/h (1 acre/h). One machine can strip about 400 ha (1,000 acres) per year.

3.5.3.3 PRODUCTION FIELD DITCHING

The design of a production field ditch layout is dependent on the capacity of the planned production equipment, mining method, the topography, and the permeability of the *in situ* peat (which itself is partially dependent on the peat type and degree of humification). The field ditches have the dual function of collecting surface runoff and lowering the water table in the immediate vicinity of the ditch. Depending upon the nature of the peat, the ditch (commonly measuring 1 m × 1 m) should affect drawdown to the centers of fields. Current operators have found that a practical ditch spacing ranges from 10 m to as much as 50 m depending upon local conditions.

For general planning purposes, a field ditch spacing of 20 m and an allowance of 500 m of ditch per developed hectare of bog, would be appropriate. Thus, in the case of a hypothetical 2,000 ha bog divided into 1,250 fields measuring 20 m x 400 m, some 1,000 km of field ditching would be required.

The equipment required for the construction of field ditches is similar to the primary ditching equipment previously described, except that the cut would be limited to 1m x 1m and that low ground pressure tractors are usually used instead of excavators. It is reasonable to plan that each ditch should be re-cut once a year and that ditching operations be carried out on a two shift basis during eight months of the year.

3.5.3.4 SCREW PROFILING

In order to accelerate the surface runoff of rain water and spring melt water, it is necessary to profile the production fields toward the ditches (in the same fashion as a city street is profiled towards the curb). A travelling horizontal screw, which is towed behind a tractor, cuts the peat along the ditch line and conveys the peats down the length of the screw to discharge it towards the center of the field. Thus, the center of the fields always drain towards the ditch line. The profile will remain as long as peat production is conducted uniformly over the entire width of the field.

Most moss peat operators in Canada generally do not profile the production fields and as a result do not achieve the higher production rates experienced in Europe. The field profiler is a $15,000 accessory machine which can be attached directly to most farm type tractors having a 3-point hitch.

3.5.4 MINE SERVICES

The installation and construction of mine services includes the following main activities:

- construction of access road, which can include cordoroy or fibre mat construction techniques for portions of road on the bog,
- clearing and levelling of equipment yard and installation of culverts to divert spring runoff water,
- preparation of well drained pad or clearing for peat stockpiles adjacent to the bog,
- water, power, communications, waste and garbage disposal facilities,
- equipment service buildings with service bays, spare parts inventory, and mine office, and
- fuel supply depot for the peat production machinery and mine service vehicles, and a heat supply for the equipment service building.

The cost of construction of mine services for peat operations is generally low due to the suitability of much of the bog pre-production equipment to mine site preparation activities. As well, pre-fabricated steel buildings are commonly used along with mobile office trailers. Accommodation on site is usually only required for security purposes.

3.5.5 MINING METHODS

Most commonly, peat mining is carried out by the milled peat (ridge and vacuum systems), sod cutting, and hydraulic or wet peat production methods. Several of these methods are used concurrently within peat producing countries as the selection of the most suitable mining method is mainly dependent on site-specific climatic and terrain conditions. For example, in Finland during the 1980 production season, 92% of all peat production was by the milled peat method and the remaining 8% was by the sod peat method. There are variations to each of the methods, the most popular of which are discussed in the following sections. Descriptions of some of the mining methods have been reported previously in other studies carried out by Monenco but have been expanded herein or included for completeness.

3.5.5.1 MILLED PEAT MINING

The first reference to the use of the milled peat mining technique was in an Irish news article written by Charles Hodgson dated July 1, 1864, which stated:

> "The bog is first thoroughly drained by deep ditches intersecting each other at intervals of about 60 yards. The upper surface of heather and loose sod is then removed and the compact bog, thus laid bare, is scarified all over with light harrows drawn by men; the loosened surface, which dries very rapidly, is scraped off and collected into heaps and the harrowing is resumed.
>
> The operation in fine weather is performed twice a day and the peat thus collected is found not to re-absorb moisture, although exposed to the weather. During the two or three hours that the loosened surface remains on the bog, if the weather be fine, it loses about 40 or 50 percent of its moisture.
>
> The partly dried turf, or 'mull' (as it is locally termed) is brought from the bog in wagons running on light rails."

The description is remarkably accurate even by today's standards, although the manual labour was replaced by modern machinery many years ago. The development of peat production equipment over the years has resulted in 2 distinctly different methods of milled peat collection, namely, the vacuum and ridge peat methods.

RIDGED PEAT METHOD. Milled ridge peat mining is based on the air-drying of a fine surface layer of fluffed peat to approximately 45% moisture content and ploughing it into ridges in the center of the production fields. The ridges of peat are then transported, by various methods, to either a bogside storage facility or directly to a thermal power plant, or other industrial users.

During bog preparation the fields are profiled so that they slope at approximately one in twenty towards the drainage system, which assists the surface runoff of rain water during the production season. After profiling has been completed, the first operation in the production cycle is the milling of the surface layer of peat to a depth of approximately 12 mm. This layer is then left to dry until it has reached approximately 65% moisture content at the surface. This is usually accomplished within one day of good drying.

Once the top of the milled layer is air-dried to 65% moisture content, it is turned over by a spoon harrow to expose the underside of the surface layer to air-drying. It can take from one to several harrowings, and a period of two to three drying days, to lower the moisture content to approximately 45%-50% and extra harrowings may be required if rain intervenes during the drying process.

Once the peat has dropped in moisture content to approximately 45%-50%, the surface layer is ploughed into ridges in the center of each production field, and then can be handled by larger capacity harvesting equipment. European peat producers average 15 harvests or passes per season.

The two principal methods for transporting peat from the production fields are the Peco and Haku systems. Both systems utilize similar pieces of equipment but transfer the peat differently to the storage piles. Under the Peco transportation system, which is popular in Ireland, the field ridges are transferred laterally from field to field until all of the production is placed into a number of central storage piles, increasing in size as additional ridges are collected. The central piles are sometimes covered with the plastic sheets to await loading and transportation throughout the year on a narrow gauge railroad system. This railroad system includes a permanent rail track along the bog side and temporary track which is laid across the fields containing the central storage piles. The temporary tracks are quite simple to move and can be relocated without difficulty. In Finland, when the Peco system is used, removal of peat from the central field is by bog-dumper or direct loading to transport vehicles.

Using the Haku system, which is most common in Finland, the peat is taken directly from the ridges by either "harvesting" or direct loading to tipper wagons. The peat is then stockpiled at the edge of the bog until it is transported by conventional means to a thermal power station. The Haku system is most suited to Ontario conditions be-

cause the peat is removed directly from the bog during frost-free conditions, thus, winter transport on snow roads on the bog is not necessary.

VACUUM PEAT METHOD. The milled vacuum peat mining method is similar to the previously described milled ridge mining method except that the collection methods for the peat differ. Under the vacuum peat production method the air-dried surface layer is gathered by a vacuum collector using front or side-mounted air suction mouths. A milling device is usually towed behind the unit to prepare the next

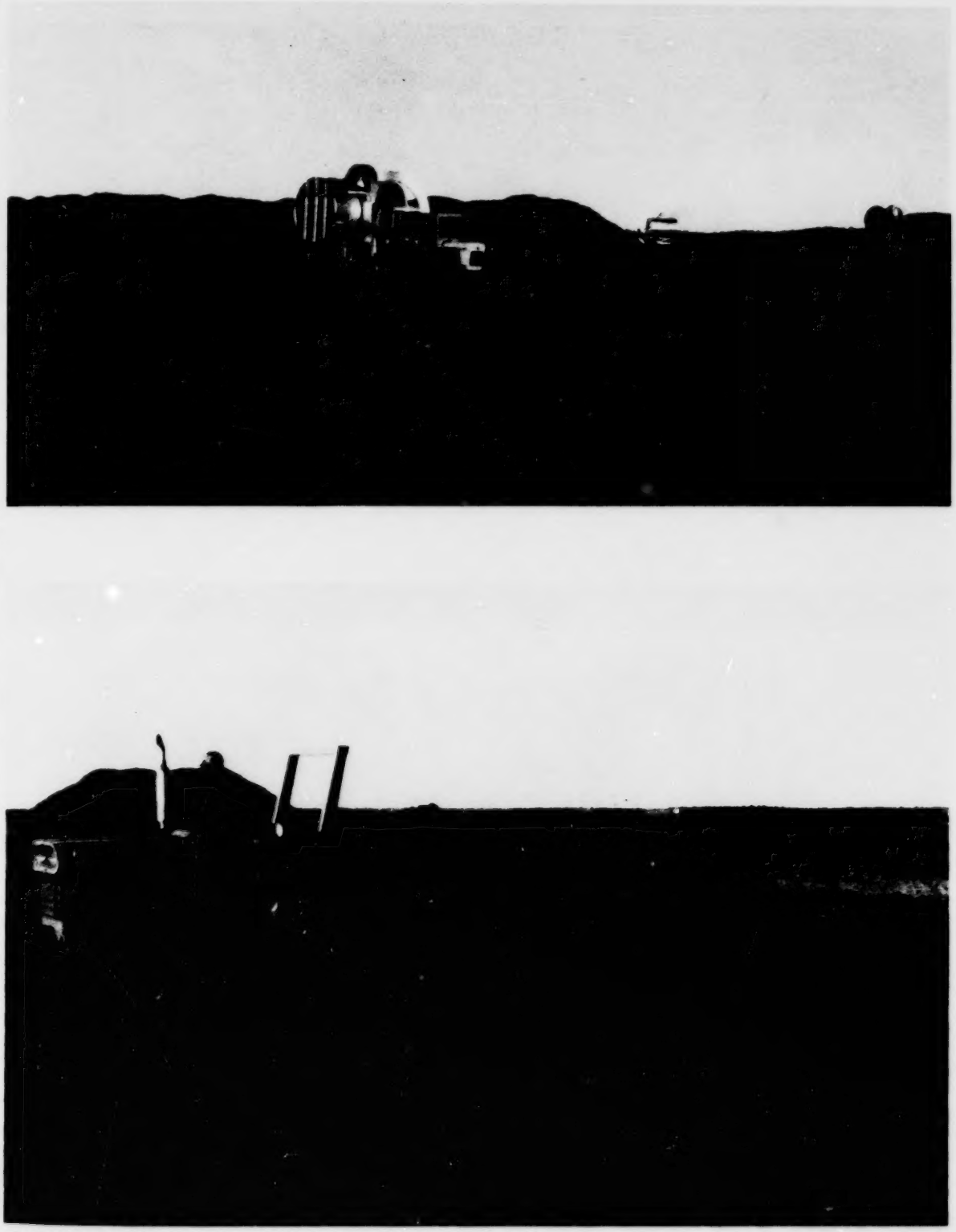


PLATE 3-11. CANADIAN VACUUM MACHINE (TOP) AND HARROW (BOTTOM).

surface layer. The air-dried peat then passes through a cyclone where it settles into a storage tank. The tank, located under the cyclone is side-dumped into a storage pile at the end of the field. From there, the peat is transported by conventional trailers or dumpers to the final storage area. The milled vacuum peat mining method completes several operations in one cycle, namely; milling, harrowing, harvesting, stockpiling and transportation.

Usually, a single harrowing is sufficient to dry the thin layer of peat to the required 45%-50% field moisture level. Vacuum collection can result in a reduction of the drying cycle from two or three days to one day when compared

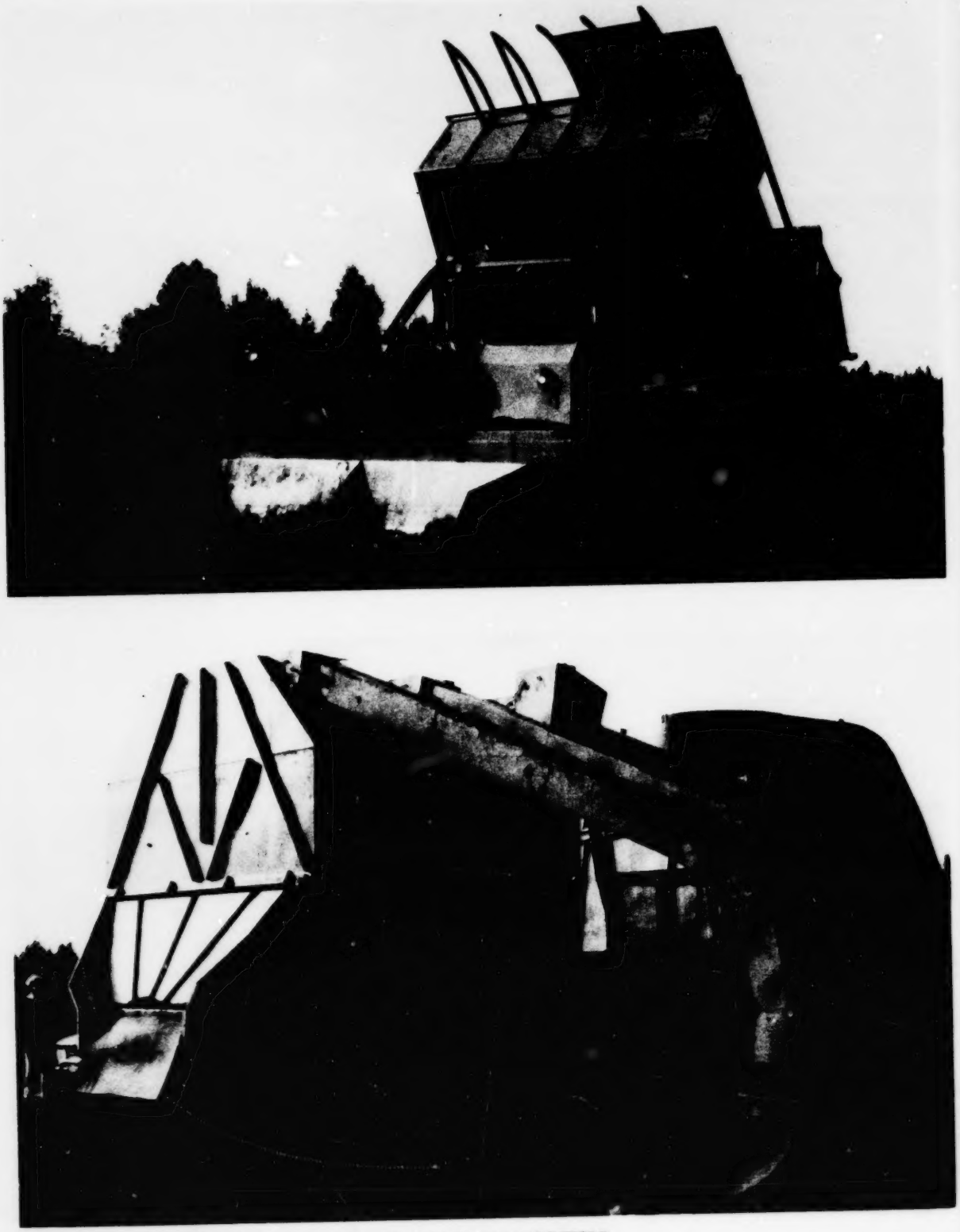


PLATE 3-12. FINISH LOADER/TRANSPORTER (TOP) AND VACUUM (BOTTOM).

with the ridge method. This is achieved because only the drier peat particles are picked up by the vacuum collector as it passes over the fields. The moisture content of the collected peat can be controlled by adjusting the ground clearance of the vacuum mouth. The surface layer picked up by this method is about 4 mm thick on average, but is not left as even as with the ridged method. Once the storage tank on the vacuum collector is filled, the machine side-dumps peat into storage piles located at one end of the field.

Field production stockpiles are located at either one or both ends of each field depending on the length of fields. As with the ridged peat production method, the stockpiles are compacted and sometimes covered with thin plastic to

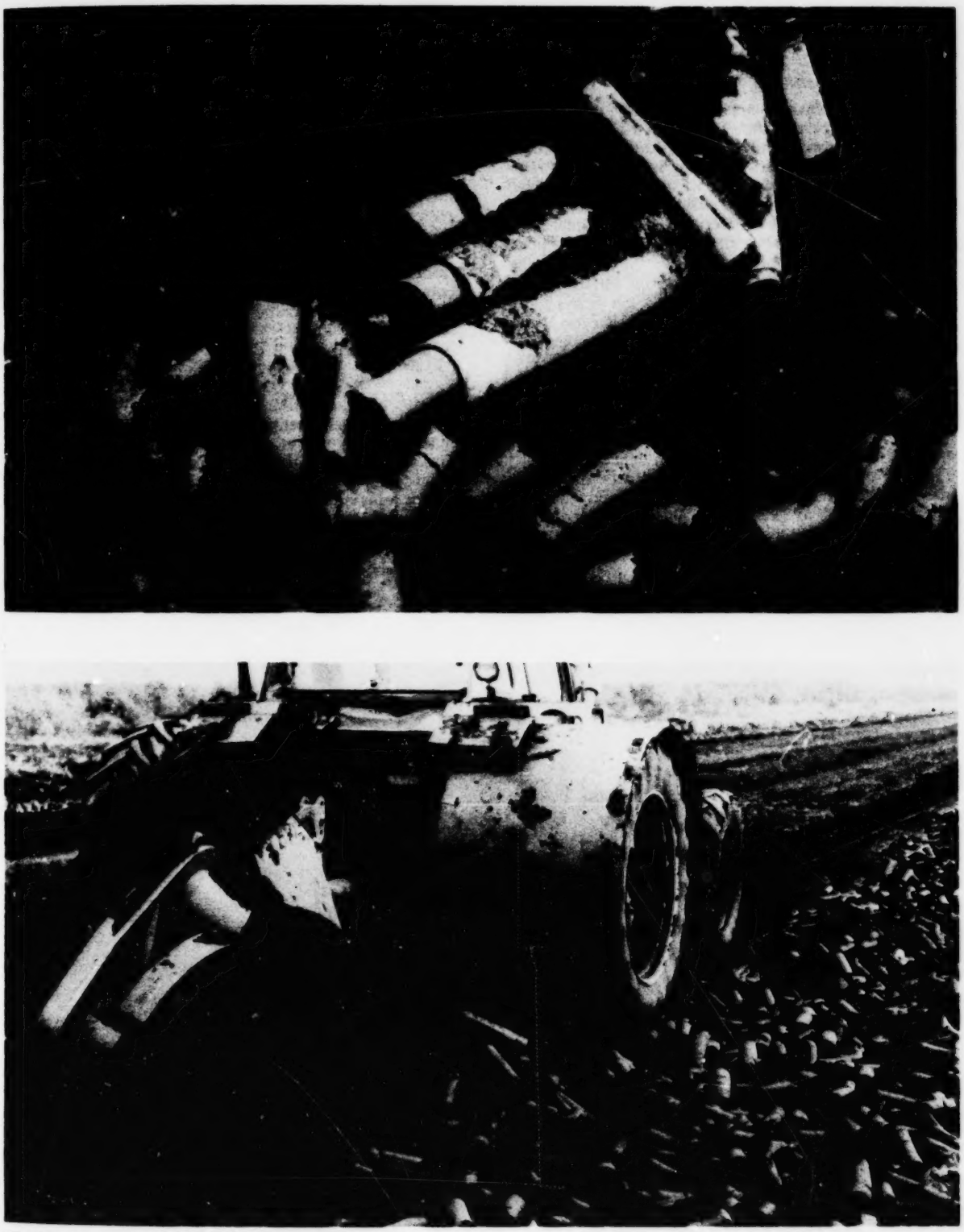


PLATE 3-13. FINNISH SOD PEAT EQUIPMENT.

protect the peat from moisture build-up, wind loss and spontaneous combustion. The piles measure 4-5 m in height and vary in length.

The peat is transported off the bog to central storage piles by special transporter or wagon. From the piles the peat can be loaded as required, to either conventional rail or truck systems for transport to the end user. Where a thermal plant or other industrial centre is located adjacent to the bog, peat is usually transported from the field storage piles to a permanent storage facility at the plant.

3.5.5.2 SOD PEAT MINING

The sod peat production method is based on air-drying lumps of peat which have been cut from the bog and mechanically extruded or stacked on the surface of the bog to dry. Specialized equipment has been designed to cut vertically into the surface of the peat to macerate the cut layer and extrude either bricks or rolls of solid peat onto the surface of the bog to be air-dried. The total sod peat production cycle involves clearing, peat cutting, windrow preparation and transportation of peat.

The first stage of the cycle is to clear the surface of loose mossy peat and prepare it in an even fashion for the sod peat cutter to pass over during the production cycle. To accomplish this, a screw cutter or profiler machine is used to level the surface of the fields.

In Ireland, sod peat is excavated by 40 tonne excavating machines "Bagger" which cut raw peat from vertical face banks or trenches (about 3-4 m deep) and pass the peat through a "macerator". The "macerator" breaks down the fibres and lumpy material and mixes the peat under pressure to produce extruded sods with greater density than the raw peat. The rectangular sods are about 10 to 12 cm square and 30 to 35 cm long. "Maceration" improves the quality of sods for the subsequent drying process.

In Finland, sod peat cutting is used only when milled peat methods are not technically feasible due to the nature of the deposit or when a sod peat feedstock is required for a small scale furnace or coke production. The Finnish sod machines produce 5 cm diameter sods by extrusion of peat through nozzles in the rear of the cutting machine (see Plate 3-13). The cylindrical sods are left on the surface of the bog for air-drying until they have approximately 75% moisture content, at which time they are stacked into windrows to continue the air-drying process. This preliminary drying process can take anywhere from 2 to 5 days depending upon drying conditions.

The preparation of windrows is necessary to clear the bog surface for the next production cycle while allowing the peat to continue air-drying. A specially designed plough is used to lift and turn the sods as it piles them into windrows. After the upper layer of the windrows has dried to 55% moisture content, the same machine is used to turn over the windrow to permit the sods in the lower portion of the piles to be exposed to air-drying. After additional drying days (5-15) the moisture content is reduced to 35%, and the windrows are gathered by a collecting machine which loads the sod peat into wagons for transport. Usually 3 complete harvests of sod peat can be made each year, and the average production per harvest would be 30-40 tonnes/ha.

3.5.5.3. BLOCK CUTTING

The block cutting peat production method is the original manual system used in Ireland to produce domestic fuel. This method dates back hundreds of years and it is still practiced, although on a minor scale. For example, in Canada it is reported that block cut peat has been used as a fuel in the north along Indian trap lines. The peat is left to dry for a year before it is used. The system basically involves

PLATE 3-14. GERMAN BLOCK CUTTING MACHINE.

the manual cutting of raw peat blocks from a vertical face. The blocks which measure approximately 30 × 10 × 10 cm are then vertically stacked on rikets (similar to pallets) where they are left to dry in the wind and sun. The length of the drying period is quite variable, but usually 2 months is sufficient to reduce the moisture content to about 30%.

Special block cutting shovels and collection wagons have been developed over the years, however, it is considered that while this labour intensive approach may be quite adequate to produce local domestic fuel, a mechanized approach is necessary if commercial quantities are to be produced. Plate 3-14 illustrates a German designed block peat cutting machine.

3.5.5.4 WET MINING METHODS

Briefly defined, the "wet mining of peat" refers to mining methods whereby peat is removed from its original site directly to the user or to artificial drying equipment without any solar drying on site. Wet mining methods offer significant advantages for potential peat utilization schemes including:

- The potential use of certain peatland areas where drainage is impossible. Bogs being mined using wet mining methods can be either drained or undrained depending on the method to be utilized. In some cases, the peatland is too low-lying (coastal areas, flood plains, behind river levees, etc.) making drainage virtually impossible.
- The possibility of a greatly increased production season and near continuous peat mining operations. Dry mining methods utilize equipment only 20%-40% of available day shift hours in a year, and
- A significant reduction in the costs of mining peat is anticipated using wet mining techniques.

The most promising wet mining method is the hydraulic system, currently used for horticultural peat production. It may become attractive in the future for fuel peat production if certain technical problems associated with it can be resolved. The hydraulic peat mining system pictured on Plate 3-15 basically follows four steps:

- dredging or other pick-up of raw peat from the unprepared bog,
- preparation of the peat slurry,
- pumping the slurry to a dewatering plant, and
- mechanical dewatering of the slurry to an acceptable moisture level.

The first 3 steps are not only technically feasible, but are also relatively low in cost, however, the mechanical dewatering operation is technically unproven for use on commercial scale operations. During the past 30 years, many mechanical systems have been tried with varied results. Generally speaking, those systems which were successful in dewatering peat to 50% moisture content, operated at a low capacity and were economically unrealistic due to the large amount of equipment necessary for commercial production quantities. Conversely, the systems with a higher production capacity could not achieve a sufficiently low moisture content.

The problems associated with mechanically dewatering humified peat are related to the colloidal content of the material, a problem which exists in many other industrial and chemical dewatering processes. Recent mechanical dewatering tests using variable pressure nip twin roller presses, originally designed for sludge dewatering, have achieved 70% moisture content levels on a relatively high capacity basis. While peat, at this moisture level, is not usable as fuel for power generation, it is close to the maximum acceptable level of 65% currently experienced in European horticultural operations.

PLATE 3-15. HYDRAULIC PEAT MINING IN BRITISH COLUMBIA.

At present, no peat processes exist on a commerical basis which operate on slurried fuel peat as a feedstock, however, much development work is underway (see Part 4). For example, peat liquefaction is being studied in Sweden, peat gasification research is being carried out in the United States, in Finland experiments with wet carbonization are underway, the Soviet Union is evaluating hydrogenolysis, and pilot-scale tests on wet air oxidation are being conducted in Canada.

Bulk peat excavation is conducted in several southern states for horticultural purposes. The peatland is first drained to lower the water table and the moisture content of the surface layers of peat. Once the peat is reduced to about 85% moisture, draglines and other similar overburden stripping equipment excavate the surface peat to a depth of about 1 m to 2 m. The wet peat is then often blended with fertilizers or wood waste and is usually sold in bulk.

3.5.5.5 SUITABILITY OF MINING METHODS TO ONTARIO CONDITIONS

There are no hard and fast rules regarding mining methods which should be used for certain bog types, peat types or climatic regions, however, based on experience at other operations there are some guidelines which can assist in selecting methods which may be most applicable to Ontario situations.

The Irish block cutting method and narrow gauge rail haulage system is considered unsuitable for Ontario since the rail system would have extreme difficulty operating in our winter climate and the excavating equipment (referred to as "Bagger" mining equipment due to its German origin) weighs over 70 tonnes and requires a very firm, well drained, deep bog on which to operate. To start a new peat industry using this system would require many years of drainage before commercial peat production could commence. The smaller German made block cutting machines could be used, but as their production rate is low and manual labour requirement high, they would not be commercially economic to operate.

The Russian and Finnish milled peat mining systems are well suited to the mining of peat in Ontario. For milled fuel peat production the ridging equipment has much higher potential output and generally costs less to operate than the vacuum pick-up equipment. The ridge equipment is recommended for horticultural peat production because it produces a better quality moss fibre product, however, current Canadian technology is more advanced in vacuum methods. Milled peat mining would be limited to areas south of the southern limit of permafrost.

The sod peat mining method is suited for use in Ontario when the final desired fuel product is in lump form. On an energy basis, sod peat will probably cost more to produce in Ontario than milled peat. However, its suitability for combustion in small-scale furnaces makes it a popular product in Finland and probably a useful product to produce in Ontario. There are generally few regional limitations to the use of sod peat mining systems, except for the permafrost areas of Northern Ontario.

Wet mining methods would be well suited to areas of shallow, unconfined peatland in the portion of the Hudson Bay Lowlands south of the zone of southern limit of permafrost. It may also be suited to wetland areas which are difficult to drain or environmentally sensitive. This mining method could not be truly applied to Ontario until its performance for fuel peat production can be proven. As much of Ontario's peat resources are located in the Hudson Bay Lowlands area, it may be of interest for the Province to undertake studies to investigate wet peat removal systems. Russia has vast peat resources located in similar areas, however, it is not known if wet removal systems have been tested there.

3.5.6 STOCKPILING METHODS

The bogside stockpiling and storage of large quantities of fuel and moss peat is a problem in most large-scale peat operations. Milled peat stockpiles, particularly where the peat is fibrous or of poor quality, need protection from both rain and wind erosion. In colder climates such as Finland and parts of Russia, the surfaces of the peat storage piles are frozen for much of the year so protection from rain is not as critical as it would be in milder climates, such as in Ireland.

Bord Na Mona reports that the use of polythene film was first experimented with on a large scale for the protection of milled peat stockpiles in the early autumn of 1961. Hurricane "Debbie" hit the country in mid-September, 1961 and thousands of tonnes of uncovered milled peat were lost. The piles that had been covered with polythene withstood the effects of the storm remarkably well. Since then an increasing percentage of milled peat stocks have been covered each year with polythene film. Likewise, sod peat and moss peat suffer from exposure to rain during the winter months, and polythene film has been widely used to cover the piles with satisfactory results.

Spontaneous combustion of certain peats in the stockpile has always been a problem with milled peat. The exothermal oxidation of peat causes the peat storage piles to attain temperatures of 60 to 70°C. Temperature probes are used to monitor internal temperatures and fire prevention action is taken when the temperature exceeds 80°C.

It was also discovered that covering piles with a film excluded oxygen and in turn, effectively prevented internal heating. This has been of considerable value to the Irish and the Russian peat industry which for many years suffered high losses from this cause. However, recent price increases in polythene film has limited its use and now preference is given to compacting storage piles with dozers to protect them from wind losses, moisture build-up and spontaneous combustion.

3.5.7 TRANSPORTATION

The physical and chemical characteristics of fuel peat are substantially different than other fuels. Transport and materials handling systems have been designed to suit the nature of air-dried peat, namely, low bulk density, methane gas generation, spontaneous combustion, poor flowability, abrasiveness and dusting. Air-dried peat, both milled and sod, is commonly transported by highway haul trucks (tractor-trailer type) and narrow gauge railway systems. The applicability of either highway or rail haulage systems to Ontario will be based on site-specific economic evaluations.

3.5.7.1 ROAD HAULAGE

Haul-truck systems are used in both Finland and the U.S.S.R. where production bogs are used to stockpile the peat and maintain 6 months to one year peat inventory at bogside.

Peat is transported year round through the use of bogside access roads adjacent to peat stockpiles. The triple-axle haul-trucks have a capacity of 40 m^3 and are loaded by front-end loaders and shovels. When coupled with a dual-axle pup trailer, the total capacity is doubled to approximately 80 m^3 and peat can be transported over distances of 100 km economically. The peat is covered with canvas to prevent wind loss and dust contamination of the roadside environment. Road vibration can cause as much as 15% compaction during transport.

3.5.7.2 RAILWAY HAULAGE

One of the most extensive peat railway haulage systems in the world is located in Ireland where over 5,000,000 tonnes of

air-dried peat is transported annually to power stations, briquet factories, and moss peat bailing plants by narrow gauge bog railways (see Plate 3-16).

Bord Na Mona, the Irish Peat Development Authority, reports that the total length of track is over 1,100 km, of which 880 is described as permanent track. The remaining 220 km is termed temporary track i.e. it is lifted and relocated up to 12 times in a year as each section of the annual 2,400 km of peat stockpiles is cleared. The sections of the temporary track are 9.14 m (30 ft) long and weigh about half a tonne. They are lifted and laid by custom built tractor with special lifting equipment.

Over 4,200 rail wagons are used in Ireland. 32 m^3 wagons are used on the more recently developed moss peat bogs. 16 m^3 wagons are standard for milled peat works and for the large sod peat works for peat delivery to power stations. Smaller wagons of 8 and 5 m^3 capacity are used on smaller sod peat works. Apart from the above, there are 750 special bogies for moving track, 10 special flat wagons for occasional movement of machinery up to 20 tonnes in weight, and 40 tanker wagons for servicing peat machinery. 50 rail cars or coaches for transport of Board employees or visitors are also in use.

Power for the rail system is supplied by 270 diesel locomotives of varying sizes up to 80 H.P. Train sizes vary from 10 to 20 wagons. The overall weight of a 20 wagon train, including 100 tonnes of peat, is 170 tonnes. Discharge from wagons is mechanical.

There are some 60 bridges and 28 level crossings on the rail system carrying county roads over the Board's rail lines or carrying the railways over canals and rivers. The largest of the bridges span the river Shannon and is 170 m with a 15 m navigation span.

3.6 PEAT MINING EQUIPMENT

The advancement of peat mining methods previously described has necessitated each peat producing country to develop its own line of peat production machinery. Over the years, many European countries have developed unique equipment designs, however, today the majority of peat equipment is built in the U.S.S.R., Finland and Ireland. Some horticultural peat equipment has also been recently developed in Canada. A discussion of the machinery is included herein.

3.6.1 RUSSIAN MINING EQUIPMENT

A complete line of peat production equipment has been developed for Russian milled and sod peat operations. Most of the equipment features the same configuration of tractor-towed accessory machinery as is employed in Finland and Canada. The towed units are either mechanically powered (P.T.O.) or are hydraulically driven and have common drawbar hitches to permit their operation in combination with a variety of tow tractors. The two principal models of tow tractors in use are the T-100 MBGS and the DT-75B which are 108 H.P. and 75 H.P. respectively. Both are wide-tracked, low ground pressure vehicles having enclosed cabs. Power is by four cylinder diesel engine and overall vehicle weight ranges from 7,500 kg for the 75 H.P. tractor to 13,500 kg for the 108 H.P. tractor. Ground pressures are reported to be 0.22 kg/m^2 and 0.27 km/m^2 RESPECTIVELY.

Most of the peat production machinery developed in the U.S.S.R. is marketed by V/O MACHINO EXPORT. The technical features of the equipment are summarized in Table 3-4. Russian peat production machinery and tractors have been

PLATE 3-16. IRISH PECO SYSTEM.

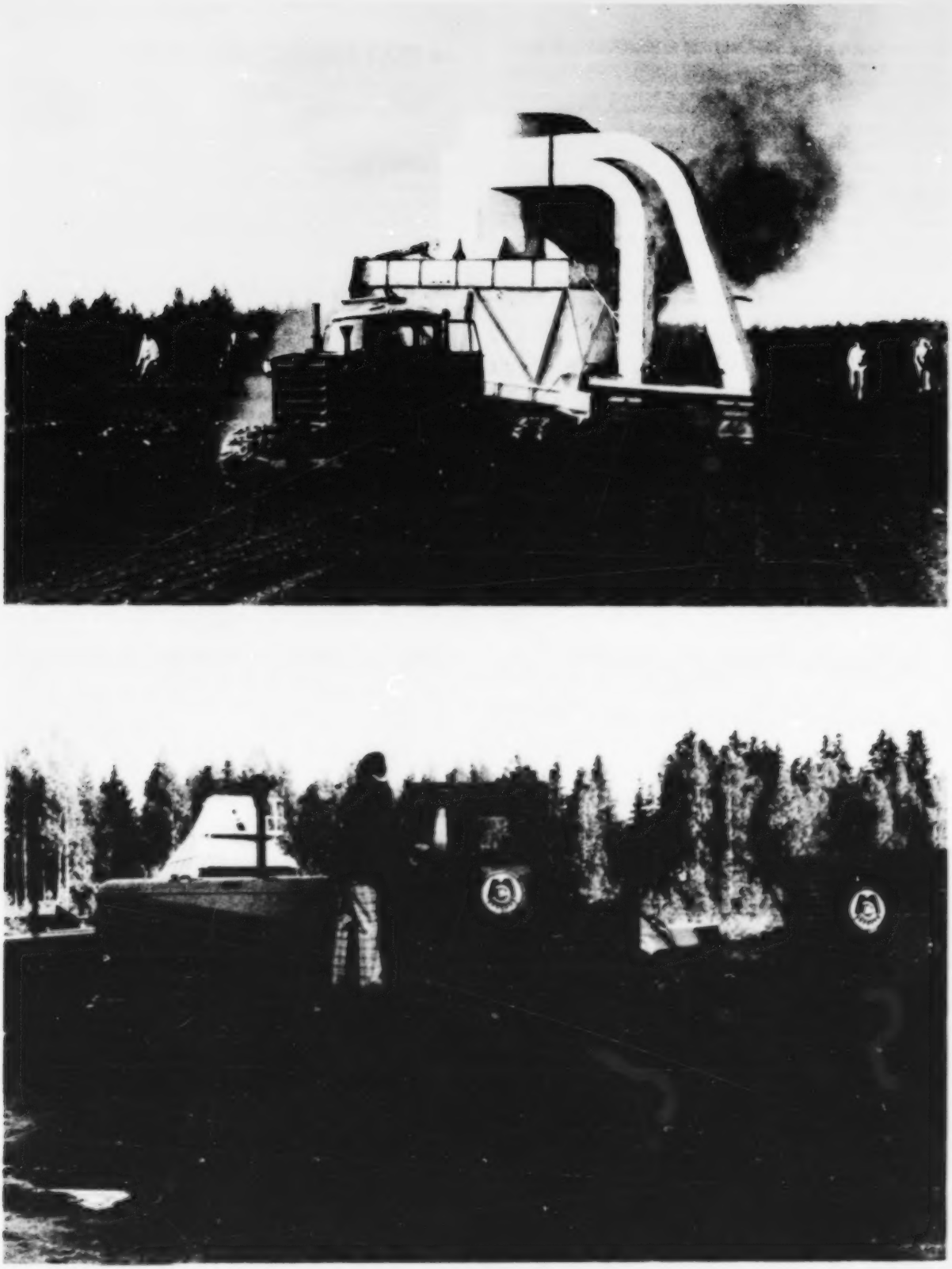


PLATE 3-17. RUSSIAN VACUUM MACHINE PPF-5 PULLED BY A DT-75B(TOP), AND PEAT TRACTOR T-100 MBGS (BOTTOM).

PLATE 3-18. RUSSIAN ROOT AND STUMP PICKER.

exported to Finland where they make up about 25% of the equipment fleet of the State-owned peat producer (VAPO). As well, over the years, some minor sales of peat equipment have been made to other peat producing countries including the United States where First Colony Farms in 1977 field tested some Russian bog preparation equipment. The Russian equipment was found to be unsuited to the unusually high wood content of the North Carolina bogs.

3.6.2 FINNISH MINING EQUIPMENT

The State Fuel Centre (VAPO) was assigned the responsibility to commence fuel peat production in 1968. While there was an existing peat industry at the time, not much experience was available for the development of domestic machinery, hence, VAPO acquired many specialized machines from abroad, particularly from the Soviet Union and Ireland.

Continued experimentation with peat production machinery has led to the development of the HAKU mining system (see Part 3.5.5.1) and associated production equipment. The chief equipment component developed for this system is a ridge loading machine which can lift peat from the ridge and load a tipper wagon on a continuous basis. A simplified drawing of the machine on Plate 3-20 shows the configuration of the two tractors, ridge loader and tipper wagon. The HAKU mining method now accounts for about 40% of all peat production in Finland.

For sod peat production, almost all existing machinery has been field tested. Shallowness, wet bog conditions and wood content in peatlands have restricted the use of some sod peat machines. The present trend of development is towards lightweight slit sodding machines, as these are small in size and their price is reasonable thus enabling sod peat production on a smaller scale. The sod peat machines functioning by this principal are also practical, as they can be pulled by conventional farm tractors. Another advantage of this sodding method is that it leaves the surface of the peat field even. Currently, 80% of VAPO's sod peat production is based on slit sodding machines, with only 20% using traditional excavators. A typical slit sodding machine is shown on

TABLE 3-4. TECHNICAL FEATURES OF RUSSIAN PEAT MINING EQUIPMENT

Name	Model No.	Description
Hydraulic Excavator	MTP-71	Self propelled full swing machine on wide tracks.
Clearing Machine	MTP-13	Self propelled full swing machine with boom mounted disc cutter.
Ditcher	MTP-32A	Tractor pulled, 1.8 m disc cutter.
Ditch Cleaner	PK-0A	Tractor pulled rotating screw ejects caved peat from ditch.
Deep Miller	MTP-24	Tractor pulled, cuts and disintegrates vegetation and roots.
Stumper	MTP-26A	Tractor pulled, extracts and ejects stumps.
Stump Loader	MTP-29	Self propelled crawler mounted stump loader.
Dump Trailer	MTP-24V	Tractor pulled, crawler mounted rear dumping stump trailer.
Continuous Stumper	MTP-81	Tractor pulled, self powered continuous stump puller/loader.
Screw Profiler	MTP-52	Tractor pulled, slant profiles production fields.
Root Collector	MTP-22A	Tractor pulled, drums spiked to pick-up and dump surface roots.
Miller	MTF-11	Tractor pulled, mills surface layer with small rotating cutting blades.
Harrow	BF-19	Tractor pulled, turns milled peat to accelerate natural drying.
Windrowers	BYF-2	Tractor pulled, scraper blades collect dry peat into windrows.
Ridge Piler	MTF-62	Self propelled, crawler mounted, conveyor type ridge piler.
Milled Peat Collector	MTF-41	Tractor pulled, bucket elevator loads windrows into bin.
Vacuum Peat Collector	PPF-5	Tractor pulled, vacuum nozzles pneumatically lift peat into tank.
Stockpiler	MTF-71	Self propelled crawler with scraper conveyor to shape peat piles.
Sod Peat	MTK-12	Tractor pulled, cylindrical sods.
Sod Collector	MTK-32	Tractor pulled, chain web conveyor lifts sods into collector bin.
Peat Loader	MMT-12	Tractor mounted clam on hydraulic boom loads loose peat and stumps.

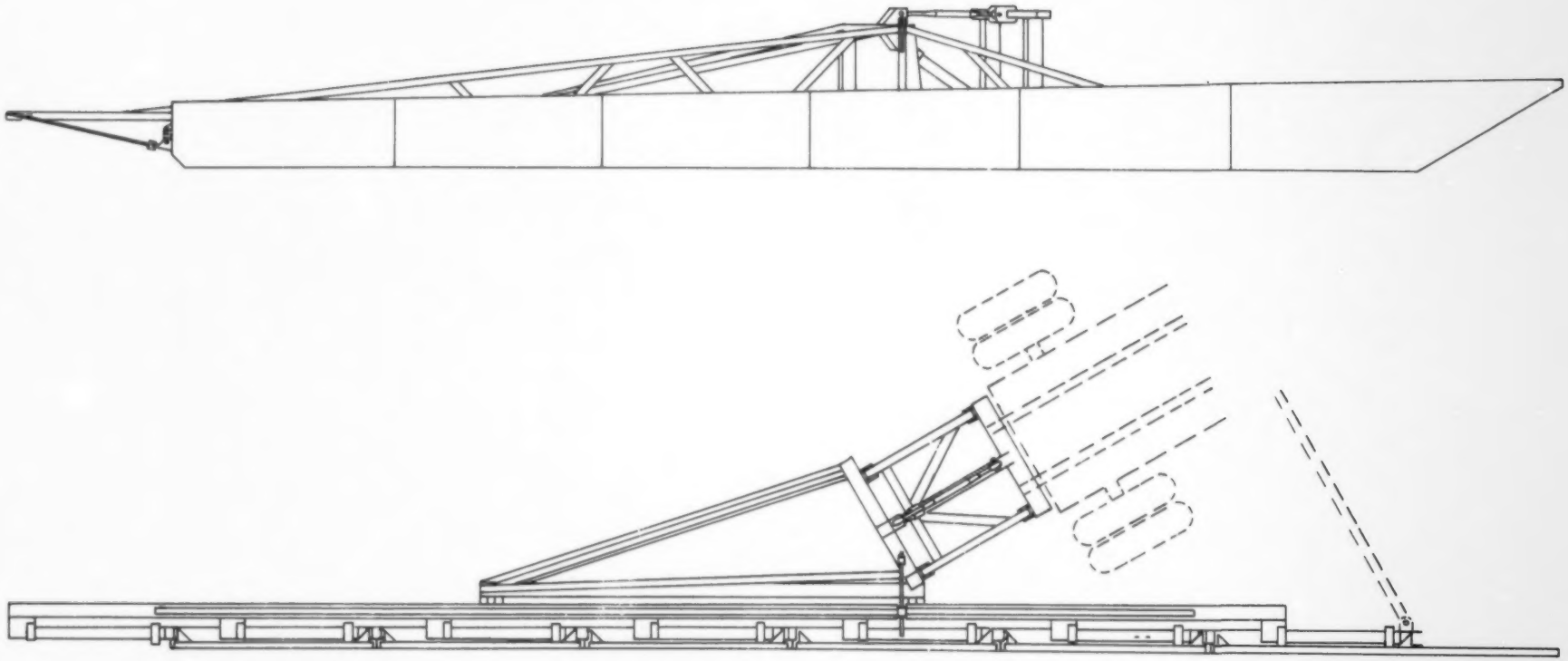


PLATE 3-19. FINNISH MILLED PEAT RIDGER.

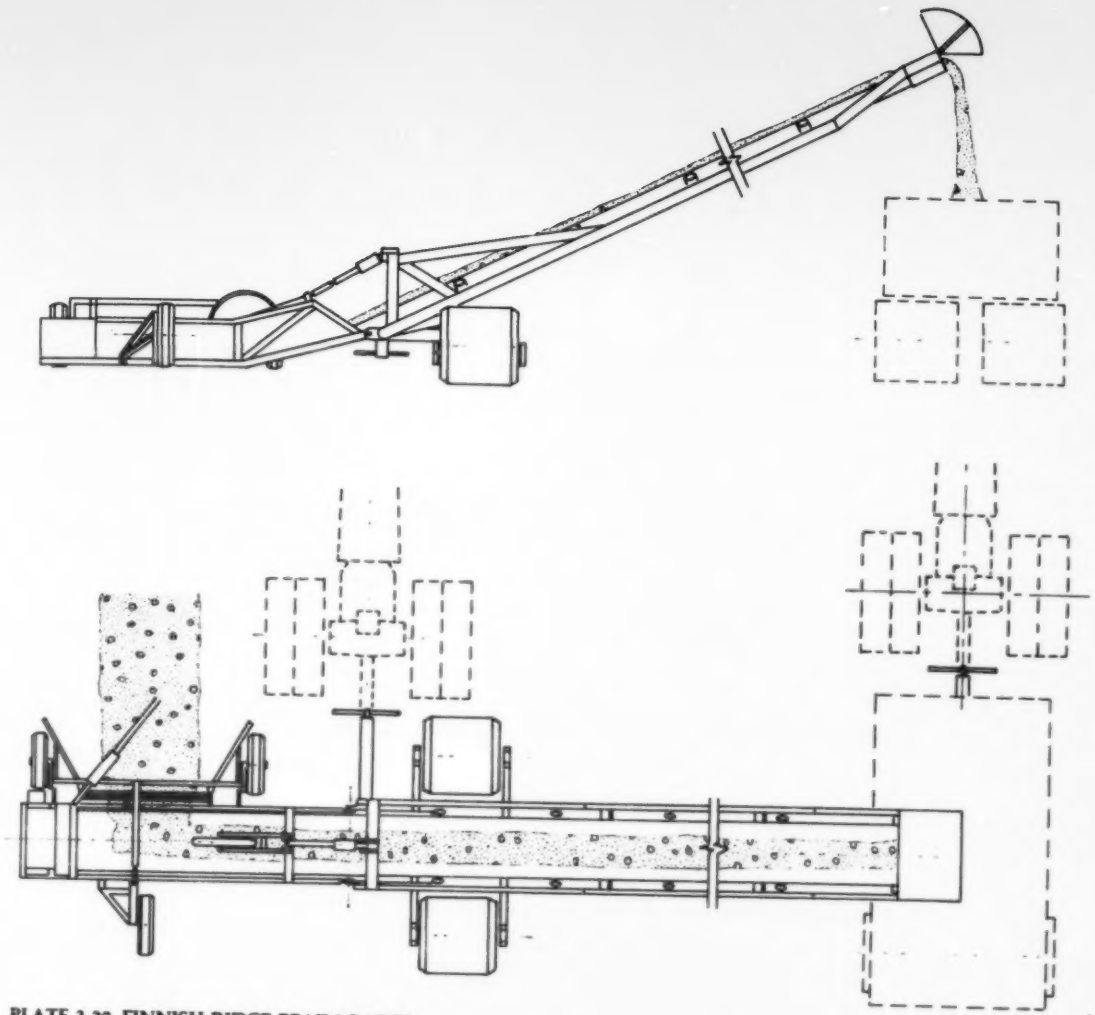


PLATE 3-20. FINNISH RIDGE PEAT LOADER.

Plate 3-21. The machines are available with a variety of cutting depths and can be mounted in tandem.

Generally speaking, the Finnish peat mining equipment is smaller in scale and lighter in weight than the high capacity Russian equipment. This makes the Finnish equipment particularly well suited to new peat operations where soft bog surfaces may be a problem. Because of the similarity in conditions between Ontario and Finland (climate, peatland, suitability of mining methods, etc.), Finnish equipment can be considered for use in Ontario until a domestic industry is fully developed.

3.6.3 IRISH MINING EQUIPMENT

A large range of specialized machinery has been developed over the years by Bord Na Mona to fulfill its sod and milled peat production objectives.

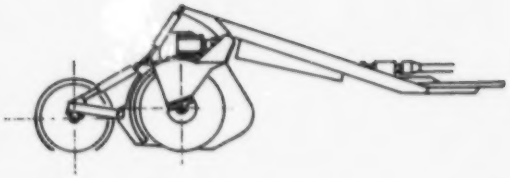
Sod peat production began in 1935 with electrically operated machines developed in Ireland by Sir John Purser Griffith. The majority of sod cutting machines now in use are of the Heseper type which are also electrically driven. While the design has changed over the years, the original was based on a steam powered sod cutting machine (Stronge and Wielandt particularly) used in Germany about the turn of the century.

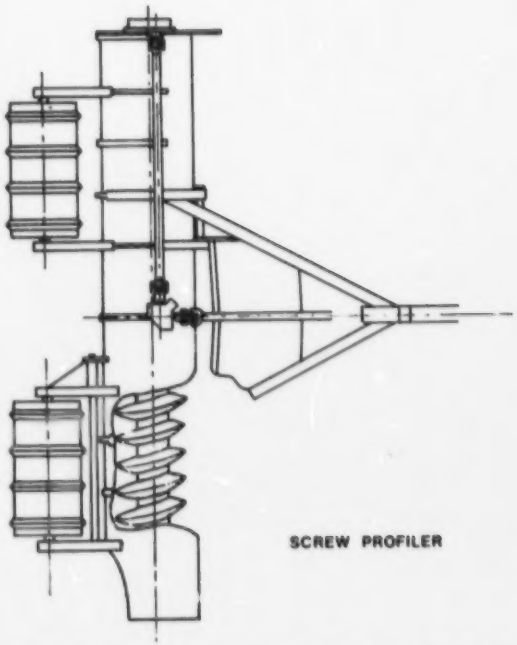
The development of the basic prototypes of milled peat equipment was actually carried out on Lochar moss, Dumfriesshire, Scotland, between 1929 and 1931 by the Peco Company. The Peco mining system, described in Part 3.5.5.1 of this report, is now widely used in Ireland and has been patented under British patent No. 412169.

The famous "Bagger-Excavators" which are used to cut block sod peat were originally imported from Germany in 1937, although the machines used today have been completely re-designed. A schematic of this machinery is presented on Plate 3-22. These excavators can weigh up to 70 tonnes and operate on a 4 m deep cutting face. After surface drying, collected peat blocks are transported by convoy or bog railways for shipment to power stations.

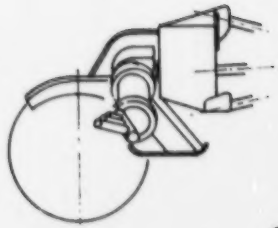
Irish peat mining equipment generally lacks the mobility, flexibility and versatility associated with the Finnish equipment. It is expected this is due largely to their earlier development and less severe climate.

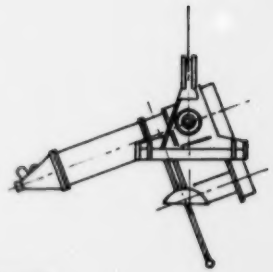
Today, Bord Na Mona is modernizing its peat equipment fleet through extensive use of hydraulic power systems and lighter weight tubular frame design. Much of the equipment is self propelled and, to date, the Irish equipment has generally not been marketed abroad.





SCREW PROFILER





SOD PEAT MACHINE

PLATE 3-21. FINNISH SCREW PROFILER AND SOD PEAT MACHINE.

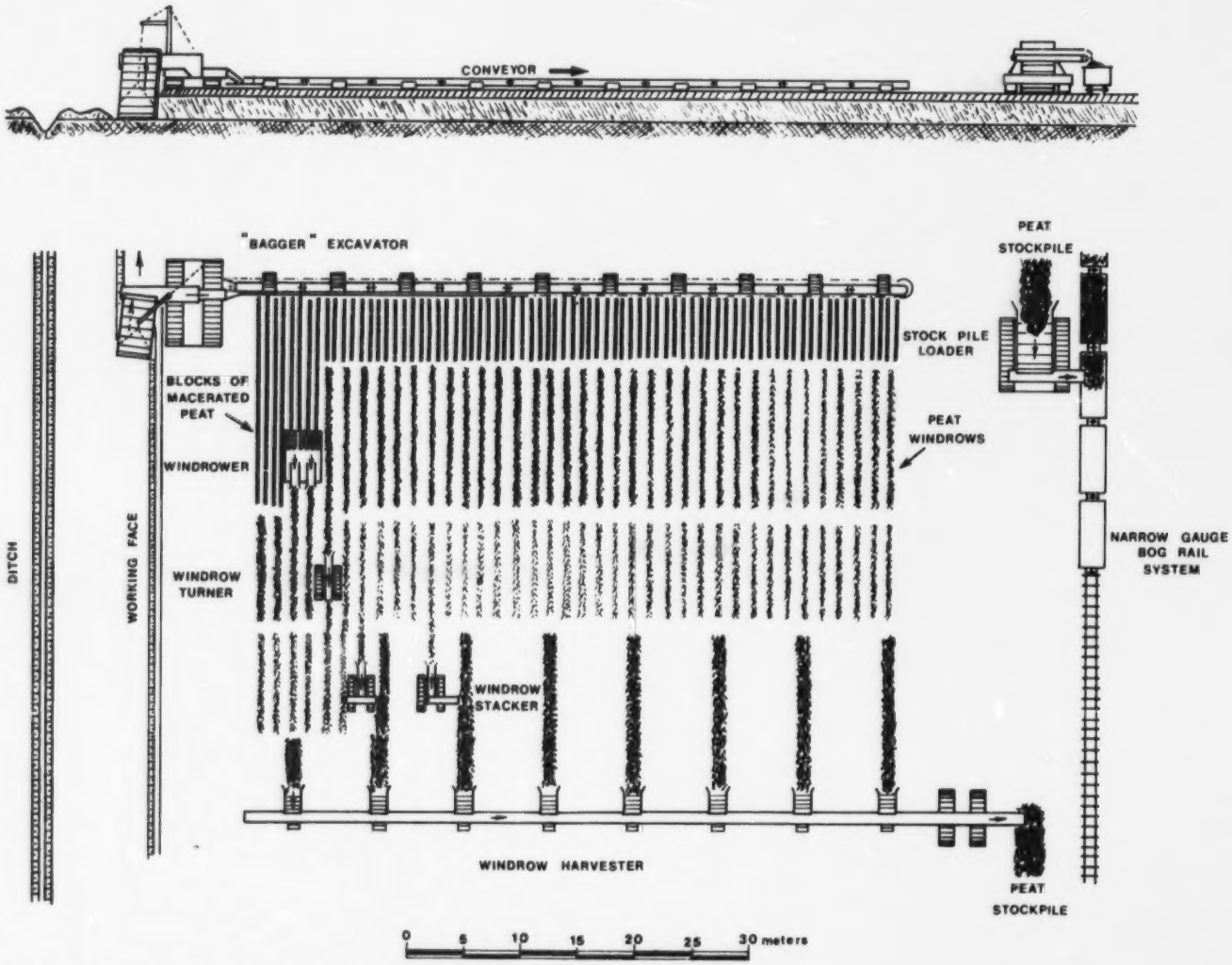


PLATE 3-22. SCHEMATIC OF IRISH "BAGGER" EXCAVATOR SYSTEM.

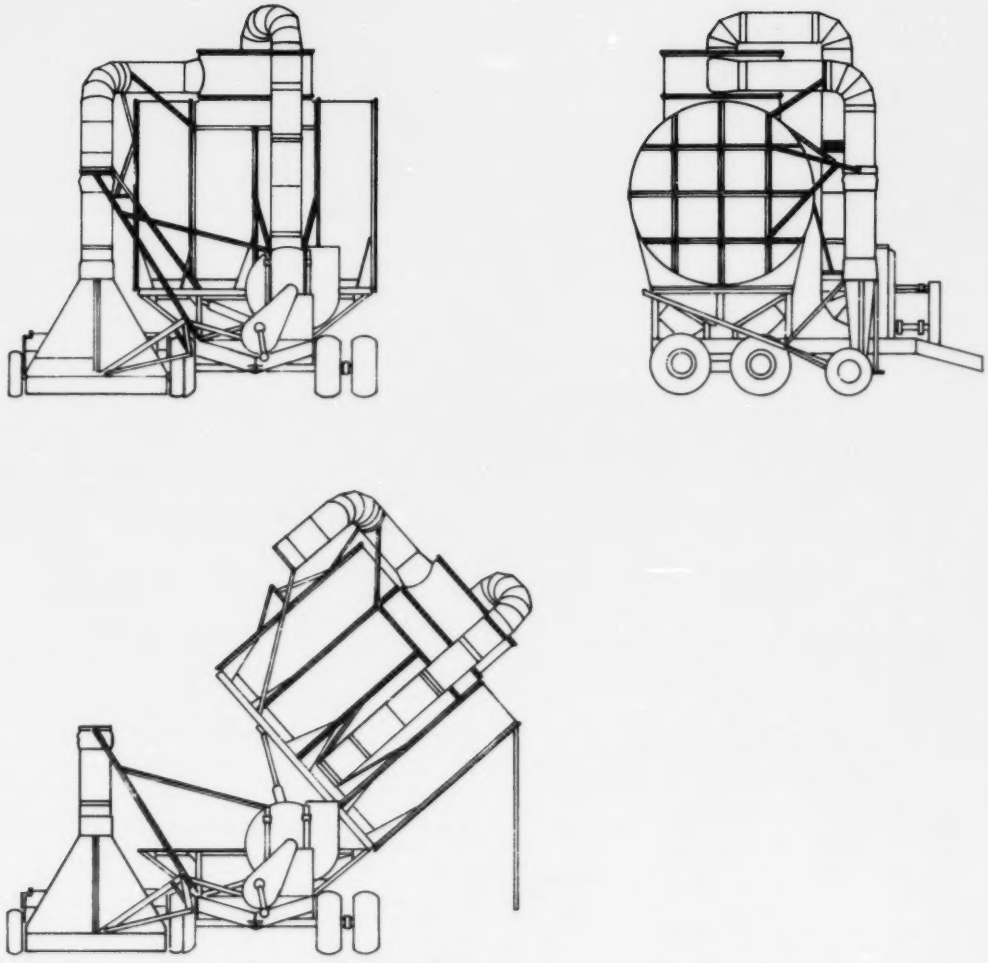


PLATE 3-23. CANADIAN MILLED PEAT VACUUM.

3.6.4 CANADIAN MINING EQUIPMENT

Peat production has been carried out in Canada since the turn of the century, although production levels were low and were primarily for horticultural and stable litter peat products. Experimental field trials were made for the hydro-peat process and wet mechanical excavation method during the 1920's and 1930's, however, none of these systems proved commercially viable.

German equipment was imported for some of the manual block cutting sod operations (Plate 3-14) and tractors replaced narrow gauge bog railway systems. It was not until the mid 1960's that the adoption of the milled vacuum peat system became popular. Many countries lay claim to the origin of the vacuum machine, however, its development for efficient horticultural peat production has definitely been achieved in eastern Canada. Manufacturers in New Brunswick and Quebec have developed a line of lightweight, low cost, high capacity vacuum equipment which has gained widespread acceptance in the horticultural peat industry in Canada (Plate 3-23) and is now exported to Europe.

Most Ontario peat producers also use the vacuum system, although none of the equipment is manufactured in Ontario. Other associated production machinery, such as ditchers and screw profilers, are imported while the tractors, loaders and other bog vehicles are usually modified Canadian farm equipment, much of which is manufactured in Canada.

3.6.5 SUITABILITY OF PEAT MINING EQUIPMENT TO ONTARIO CONDITIONS

The bog preparation and peat production machinery available on international markets can be classified into 3 main groups:

- tow tractors,
- powered accessory equipment, and
- non-powered accessory equipment.

Equipment in the first group "tow tractors" is rather self explanatory and includes standard agricultural type 2-wheel and 4-wheel drive tractors with special control modifications for peat work.

The "powered accessory equipment" in the second group includes machinery which is powered by the tow tractor, such as ditchers, screw profilers, millers, vacuums, and self powered ridge loaders.

The third group "non-powered accessory equipment" has push/pull machinery which does not require additional power take-off from the tow tractor. Typical equipment in this category would include tipper wagons, harrows, ridgers, finger wheel rakes, etc.

3.6.5.1 TOW TRACTORS

Most countries modify existing lines of agricultural farm tractors to meet the requirements for a peat production vehicle. Such modifications and/or options can include the following:

- 4-wheel drive, dual rear wheels
- 12 speed multi-power transmissions, reduction gearbox
- vertical exhaust system
- roll-over safety protection cab, escape hatch in roof
- 3-point hitch (category 2)
- drawbar
- independent power take-off (540 R.P.M.)
- split torque clutch
- pressurized cab, filtered heated air, wipers, door locks
- dual spool hydraulic power take-off
- air compressor with hose and meter
- driving lamps
- dry-air cleaner with pre-cleaner
- electrical winch
- split rear brakes

There are many tractor manufacturers who currently produce equipment which can be well suited to Ontario conditions. Four or five of the largest tractor manufacturers have plants in Ontario and it is reasonable to suggest that local manufacturers be considered for the supply of modified tractors for an Ontario peat industry.

The use of locally built tractors has the advantage of low shipping costs, high availability of spare parts, and operator familiarization with equipment. The only disadvantage may be that European-built peat tractors have other integrated design features which may not be possible to incorporate into an Ontario-built tractor without substantial design changes. It is hoped that as the Ontario peat industry develops, an Ontario tractor manufacturer will fabricate a specialized peatland tractor.

3.6.5.2 POWERED ACCESSORY EQUIPMENT

Almost all powered accessory equipment is operated by a standard 540 R.P.M. power take-off (P.T.O.) and a standard 3-point hitch (category 2) at the rear of the tractor. Power controls are usually through hydraulic spools also located in the rear of the tractor. Some front-end equipment units such as ridgers, and loader buckets are attached by sub-frame assemblies and are hydraulically powered. Some powered accessory equipment requires several hydraulic controls, thus peat tractors will usually have large capacity hydraulic systems and auxiliary hydraulic spool hookups.

The Russian accessory equipment is generally very heavy and usually requires the use of 75 H.P. - 100 H.P. tow tractors. Tractors of this size are not only more expensive, but are difficult to handle, are less fuel efficient, and tend to sink into the bog. Most bog operators prefer lighter weight 50 H.P. - 60 H.P. tractors. As well, the availability of Russian spare parts may pose difficulties.

The Finnish line of accessory equipment includes all the attachments necessary to mine peat. Each machine is powered by standard P.T.O. drive and can be mounted on either a standard category 2-3 point hitch or pulled by a drawbar. Tractor power of 40 H.P. to 70 H.P. is usually required. Virtually all of the powered accessory equipment available from Finland is technically suited to Ontario conditions and will attach directly onto Ontario-built tractors. An advantage of Finnish equipment includes the years of development work which have gone into the design of the production machinery. The main disadvantages of Finnish equipment are cost and long delivery time of equipment and spare parts.

Some powered accessory equipment is now being fabricated in the Province of Quebec (which has a 250,000 tonne per year peat industry). This peat equipment includes vacuums, screw profilers and root loaders. The equipment is well constructed, low in cost, and spare parts are readily available. The only disadvantages are that some of the equipment requires greater floatation for use on virgin bogs, and the variety of equipment is limited.

3.6.5.3 NON-POWERED ACCESSORY EQUIPMENT

Many pieces of non-powered equipment are similar to those used in farming. For example, pre-production bog development machinery such as rotovators, choppers, finger wheel rakes, tipper wagons, stump pullers, and bush cutters are already available from agricultural equipment suppliers in Ontario, perhaps with minor modifications. Thus, there is probably no need to secure this equipment from outside of the Province. The required operating power to tow the accessory equipment is in the 40 H.P. to 60 H.P. range.

3.6.5.4 RECOMMENDED EQUIPMENT FOR ONTARIO CONDITIONS

While complete lines of bog preparation and peat production machinery are manufactured in Ireland, Finland and the U.S.S.R., only some of the equipment may be available or suited to Ontario conditions. As well, Germany also produces special purpose peat equipment. German block peat machines, ridgers and Mercedes-Benz tractors are in use for horticultural peat production in at least one location in New Brunswick.

In Ireland, Bord Na Mona does not manufacture peat production machinery for foreign export, so it appears that the Irish equipment is not available to Ontario. Similarly, Russian equipment is manufactured primarily for domestic use. However, recent North American market advertising by Machino Export includes peat production machinery. Technical equipment specifications received from the Russian equipment representative indicates that their machinery is substantially heavier, expected to cause floatation problems on new bogs, consumes more fuel, and costs more than other alternative machines. It is also suspected that spare parts may be difficult to acquire. Russian powered accessory equipment is not compatible with standard tractors.

The Finnish line of equipment is generally compact, lightweight, and should be well suited to Ontario conditions (physiography, climate, and peat types being similar to Finland). The peat machinery is compatible with standard Canadian tractors and recently arrangements have been

TABLE 3-5. EQUIPMENT SUITABILITY TO ONTARIO

	Country of Origin				
	Canada		Finland	Russia	Germany
Equipment	Ont.	Que.			
Tractor	•				
Ditcher		•	•		
Rotovator	•				
Bush Cutter	•				
Stump Puller	•				
Screw Profiler		•	•		
Miller			•		
Harrow		•	•		
Vacuum		•	•		
Ridger			•		•
Ridge Loader			•		
Front-End Loader	•				
Sod Cutter			•		
Tipper Wagon		•			
Finger Wheel Rake	•				
Windrower			•		
Block Cutter					•

made to inventory some of the spare parts in Canada. Equipment quotes recently received from Finnish peat equipment suppliers indicate that their equipment can be expensive and in cases where a similar machine is available locally, substantial savings can be realized. Of course, this situation can change with fluctuations in exchange rates and North American market demand for peat machinery.

In order to clarify the suitability of various international peat machinery available to Ontario, Table 3-5 has been prepared showing equipment technically suited to Ontario, and the country of origin.

3.7 ONTARIO PEAT PRODUCTION COSTS

3.7.1 METHOD OF STUDY

Currently there are several small horticultural peat producers in Ontario and cost data on some of these operations is available. However, as different mining methods and equipment is expected to be most suitable for large-scale fuel peat and/or horticultural peat production in Ontario, reference to the costs would be misleading.

Consequently, the most recent fuel peat mining costs and production data acquired during a number of visits to peat producers in Ireland and Finland and also to New Brunswick have been considered. As well, mining cost estimates have been prepared by Company peat specialists during the course of a number of peat investigations and have been based on price quotations received from equipment suppliers and actual labour and operating costs incurred by large-scale horticultural peat producers in Quebec and New Brunswick. The latest available information on mining costs has been used to develop an Ontario peat production cost estimate. First, costs were converted to a 1981 basis. Next, a preliminary ranking by climate of the various regions of Ontario was performed, including estimated duration of production season, and compared to Finland and New Brunswick to forecast unit area production rates and costs. Both sod and milled peat production rates and costs were estimated by this method. To obtain greater accuracy, site-specific investigations will be required including first principles capital and operating cost determined.

3.7.2 PEAT PRODUCTION RATES

The success of conventional peat production methods, such as sod and milled peat, is dependent upon solar drying conditions during the May to September production season. As discussed previously, the influence of climate and weather on peat production has not been determined quantitatively, however, a relationship between unit area production rates and various climatic regions can be recognized (current research in Finland is now underway studying the influence of climate on peat production). Sod and milled peat production rates for Finland and New Brunswick are well recorded and comparison of climate has been made with that of Ontario to determine approximate unit area production rates (and costs) for peat production for various regions of the Province.

Table 3-6 summarizes the production and cost data for Finland, New Brunswick and Ontario as determined from the ranking of regional climates. Historical milled and sod peat production data are shown for Finland and New Brunswick.

3.7.3 PEAT PRODUCTION COSTS

3.7.3.1 MILLED AND SOD PEAT

Table 3-6 shows estimated milled peat production costs for various Ontario regions ranging from $18.00 to $24.00 per tonne (at 50% moisture content). No milled peat production was considered available from the Hudson Bay Lowland area due to discontinuous permafrost. Sod peat is estimated to cost between $31.00 and $40.00 per tonne at 35% moisture content (excluding data from the Hudson Bay Lowlands). As discussed previously, the cost estimates are based on actual European operating data and recent detailed Canadian fuel peat studies adjusted to meet Ontario climatic and operating conditions. The peat is costed at bogside stockpiles and is based on an owner-operator development scenario over a 25 year mine life. It has been reported by VAPO that the average 1980 peat consumer prices in Finland were approximately:

- $23.00/tonne - milled peat at 50% moisture content
- $38.00/tonne - sod peat at 30% moisture content
- $78.00/tonne - briquets at 10% moisture content

TABLE 3-6. ONTARIO PEAT PRODUCTION RATES AND ESTIMATED COSTS.

Climatic Region	Annual Peat Production Rate		Estimated Costs	
	Milled**	Sod***	Milled**	Sod***
	tonnes/ha	tonnes/ha	$/tonne	$/tonne
Southern Ontario (Ottawa-Barrie)	200	140	18	31
Northeast New Brunswick	180*	120	20	33
Central Ontario (North Bay-Sudbury)	170	110	22	35
Western Ontario (Fort Frances-Kenora)	170	110	22	35
Finland	160*	100*	23	38
Northern Ontario (Kirkland Lake-Timmins)	140	90	24	40
Hudson Bay Lowlands	N/A	60	N/A	62

* Based on reported production data
** at 50% moisture content
*** at 30% moisture content

In both the sod and milled peat cases, the costs are for loose peat stockpiles adjacent to the bog and are sized approximately to a 100,000 tonne per year mining rate.

The estimated cost of peat includes all bog development costs, access roads, ancillary facilities, mining equipment, as well as bog operating costs, mine management, and equipment maintenance. Royalties, license fees and land acquisition costs are not included. The cost of sod and milled peat for each Ontario region is expressed as the levelized cost of peat produced and stockpiled over a 30 year period, given in mid 1981 dollars, which is equal to the present worth of total costs divided by the present worth of the amounts of peat produced. The levelized cost calculation is a method of deriving an average all inclusive unit cost of peat production over the total project life.

In this derivation it is assumed that cost/price relationships remain constant over the life of the project. The levelized costs given in Table 3-6 are based on an assumed real cost of capital of 8%, however, sensitivity analyses have shown that the unit cost of peat is not especially sensitive to the assumed cost of capital.

The data in Table 3-6 shows that peat production costs in the Kenora-Fort Frances region as well as the North Bay-Sudbury region are similar to peat production costs in Finland and slightly higher than in northeast New Brunswick. Costs in the Ottawa-Barrie regions are estimated to be lower than in both Finland and New Brunswick and, based on the preliminary analysis of climate, this region may have the highest peat production rate potential in Canada.

3.7.3.2 WET MINING PEAT COSTS

The wet mining of peat includes such excavation methods as dredging, high pressure monitor cutting and dragline stripping (as described in Part 3.5.5.4 of this report). The peat is excavated in a wet state (moisture content over 90%), however, many years of dewatering studies and pilot tests have failed to achieve an *economic* means of dewatering fuel peat (in some cases moss peat can be economically dewatered due to its higher market product value). However, there are peat processes under development which require a wet feedstock, therefore dewatering of the peat feedstock would not be necessary. The processes are not commerical at this time, however, they are of interest because it is possible to wet mine about 8 months a year as opposed to 3 months for solar dried peat. As well, wet mining features a one pass mining method which may be more environmentally attractive in some areas of Ontario. For example, a 100,000 tonne per year milled peat operation would require about 600 ha of peatland to be under production at one time, whereas wet mining would only require about 30 ha of production area at one time. The smaller area is actually a travelling pit which would take in the total 600 ha over the total mine life.

Wet fuel peat mining costs are difficult to estimate as there are currently no active operations nor have detailed wet mining studies been conducted. However, information on file from dredging contractors, hydraulic moss peat production and other sources indicate that the cost of excavating and delivering peat in a wet or slurry state could vary from $2.50 to $5.00 per tonne (90% moisture content). Mining method, peat type, climate, and transport distance will greatly influence wet mining costs and costs will need to be determined for each proposed site.

For purposes of evaluating the J-P Energy OY wet carbonization process described in Part 4, we have used a wet peat mining cost of $3.80 per tonne (at 90% moisture content). For the size of operation considered this can only be considered very approximate since detailed mining cost estimates have not been prepared.

3.8 SUMMARY OF MINING METHODS, EQUIPMENT, AND COSTS

Conventional mining methods, such as the milled and sod peat systems used in Finland, are well suited to Ontario conditions and should present no implementation problems at least in the area south of the southern limit of permafrost. Irish mining systems, featuring narrow gauge rail transport, would probably present difficulties in Ontario because of the more severe winter conditions. Wet mining fuel peat systems and associated processes are not yet commercially proven and require much research and development. Wet mining has an application for horticultural sphagnum peat production, however, low cost energy supplies must be available to economically dry the peat from 70% to 50% moisture.

Most of the self-powered mining equipment, such as tractors, are manufactured in Ontario and with certain modifications could be well suited for peat operations. All of the Finnish peat production machinery is compatible with these tractors and is recommended for use when Canadian-built machinery is not available. Ireland does not manufacture peat equipment for export and Russian peat equipment, while being suited to Ontario, is excessively large, heavy, and is not generally compatible with Canadian-built equipment.

Fuel peat is currently not commercially produced in North America, thus, peat production cost estimates for Ontario have been based on costs experienced in Ireland and Finland as well as other detailed studies prepared recently in Canada. It is estimated that Ontario milled peat production costs will be in the range of $18.00 to $24.00 per tonne (at 50% moisture) and sod peat costs will be in the range of $31.00 to $40.00 per tonne (at 30% moisture) excluding costs for Hudson Bay Lowlands. More accurate cost estimates will be possible once demonstration projects and monitoring systems are in place.

PART 4
Peat Processes

4.1 INTRODUCTION

4.1.1 GENERAL

This Part contains information on the state of the art of peat dewatering, beneficiation and processing technology and represents the main effort of the sub-consultant (Ontario Research Foundation) to the study. It has involved:

- a survey of world-wide process research, development and commercialization activity aimed at the dewatering and beneficiation of peat and at developing physical, chemical and biological processes which yield saleable products,
- identification of products including solid, liquid and gaseous fuels, absorbents and the like which have potential domestic and/or export markets,
- determination of the required physical and chemical characteristics of peat that govern its potential use for energy and non-energy products,
- development of a preliminary list of process-trains including constraints to, or requirements for, peat quality, mining method and scale of operations,
- selection of certain processes for a listing of performance relative to size of operation, capital and labour requirements, and
- a listing of recommendations relative to (a) preferred processing options on site-specific basis, and (b) future courses of action and development initiatives to be taken.

4.1.2 INFORMATION AVAILABLE

The technical literature has been reviewed as well as information provided by the proponents of commercially available technologies. Engineering judgement has been applied in the evaluation of the data, however, no verification of claims made was possible at this level of study. On account of the rapid technological development of the industry, in many instances, process economics were projected from feasibility studies which in turn were based on the results of pilot studies rather than production-scale processing experience.

Selection of particular processes for detailed examination does not constitute their endorsement over others by the authors of this report. The information provided herein is not intended to serve as the sole basis for investment decisions.

4.1.3 COST EVALUATIONS

Capital cost figures were based on data provided by the source of the technology. These varied as to the detail to which the estimates were carried out. In some cases, it was necessary to add factored estimates for installations, auxiliaries, working capital, etc. The costs are given in Canadian dollars (mid-1981), unless otherwise noted. The bases of capital cost estimates are given in each case.

Annual capital charges were calculated using a capital recovery factor (CRF), which provides a levelized return of capital plus return on the capital investment, over the assumed service life of the project. A nominal cost of capital of 20% per annum has been assumed, on a before tax basis. It is recognized that variations on these criteria are possible which should be investigated if further studies of these processes are undertaken.

Labour cost was estimated to be $20,000 per man-year in the case of single unit operations; $30,000 in the case of complex installations requiring administrative overhead.

Foreign currency conversions were calculated on the basis of C $1 = $0.83 U.S. and C $1 = 3.66 Finnish marks (FMK).

4.1.4 THERMAL EFFICIENCIES

Unless otherwise noted, the thermal efficiencies of the processes described were calculated on the basis of higher heating values of feed and products according to:

100 × (heating value of products, MJ/kg) ÷ (Heating value of feed, MJ/kg product) + (Thermal equivalent of electrical energy, MJ/kg product) + (other fuels, MJ/kg product) = thermal efficiency of process, %.

4.2 PEAT AS A FEEDSTOCK

In the course of describing various technologies using peat as a starting material, it may be found that there are several parameters of peat quality that will have to meet specified values in order for the process to work and/or to produce a saleable product of the appropriate quality.

The combination of peat quality parameters tend to be quite site specific. There are those who go as far as stating that peat from each bog is different if one takes a close enough look. Fortunately, most processes admit a fair range of variation in the feed specifications. Nevertheless, it may be necessary to conduct pilot evaluations of peat samples to accurately predict the performance of the chosen process.

These parameters and their significance are briefly described below, and the applicable values will be given in the discussion of each process. When considering a particular process for a given site, it is necessary to determine that the physical and chemical properties of the resource are suitable for the application.

Methods for the determination of the parameters listed below are given in the Peat Testing Manual (National Research Council, Canada, 1979).

(i) DEGREE OF DECOMPOSITION, OR HUMIFICATION. Of the many systems in use world-wide, the von Post scale has been employed in this report. The reader is referred to the description given earlier in Part 2.

For those applications that might make use of the fibrous nature of peat (e.g. agricultural and absorbent uses), a low degree of humification is desirable (H1-4). Although it is possible to use peat as low as H3 for fuel, it is generally recognized that the best peat for fuel or chemical feedstock use is well decomposed, dense peat classified at H5 or higher on the von Post scale.

A linear relationship between the degree of humification and heat value has been shown using regression analysis for a series of bogs in Newfoundland (Tibbetts, 1976; Monenco Ltd., 1978).

(ii) BOTANICAL ORIGIN. A given mass of peat consists of residues of the flora dominant at the time of formation: mosses (e.g. Sphagnum, Hypnum, etc.) or higher plants (grasses, reeds, sedges). In addition, many bogs will contain varying amounts of woody material and roots which have to be removed or homogenised with the peat before it enters the processing plant. The botanical makeup of the peat may have an influence upon the performance of mechanical dewatering equipment, and the minimum ash content of the peat.

(iii) ASH CONTENT. This is the percentage of peat solids that remain after oxidizing the dry sample at 550°C in a muffle furnace. In addition to the mineral salts contained in the vegetable matter, the ash includes silica and clay particles which found their way into the bog in the course of its formation. Since lower plants (mosses) require less mineral nutrients for their growth than grasses and sedges, Sphagnum peat, in the absence of mineral particles may have ash content as low as 2%, compared with a minimum of 3-4% for reed-sedge peat. The admixture of mineral soil can raise the ash content considerably above these figures.

The ash content of the peat feedstock is an important characteristic on two counts:

- silica particles can cause erosive wear in process equipment
- the ash content of the feed is reflected in the product, and low-ash fuels are always more desirable.

(iv) MOISTURE CONTENT. The moisture level of the peat entering the processing plant depends on the method of mining employed. In the bog, peat may contain over 90% moisture, or more than 9 kg water per 1 kg of solids. With the exception of some biological methods, the peat has to be dewatered to yield useful products. Most of the peat in use today is dried to 30-50% moisture by the use of solar energy in the course of mining. Wet mining techniques have also been proposed, which deliver the peat with 80-90% moisture as mined.

Since the economics of peat processing are vitally dependent upon the cost of removing water in the course of processing, the process trains proposed for any application must carefully co-ordinate the mining method, dewatering technique and the requirements of the actual process.

(v) ELEMENTAL ANALYSIS. A significant advantage of peat over coal as a fuel is its lower sulfur content, enabling it to achieve a premium price per unit of energy in many applications. Low sulfur content is also desirable in the production of substitute natural gas and methanol via syngas.

The ratios of carbon to hydrogen and oxygen vary somewhat among peats. They are considered in the detailed design of methane and methanol synthesis process steps. Nitrogen is present in small amounts (1-3%) and may be recovered as ammonia from large-scale gasification systems.

(vi) REACTIVITY TO GASIFICATION. The design and economics of substitute natural gas (SNG) and synthesis gas processes depend on experimentally determined reaction rates for devolatilization and char gasification.

(vii) BULK DENSITY. This is a parameter significant in evaluating material handling, storage and transportation economics, both for starting materials and products.

(viii) WETTABILITY AND ION EXCHANGE CAPACITY. These parameters are significant in agricultural and environmental improvement applications.

4.3 DEWATERING

4.3.1 GENERAL

The most difficult technical obstacle to utilizing peat as a raw material is the reduction of its high associated water content. Peat, as found in nature, may contain over 90% water. Plate 4-1 shows the reduction in water necessary to achieve an acceptable feedstock for further processing. The peat-water affinity is due to several mechanisms: hydrogen bonding, solvation of colloids and retention by capillary forces. These factors may be disrupted by mechanical force or the application of thermal energy.

It is crucial for the economic success of any peat processing train to minimise the use of fossil fuels in reducing the moisture content of the feed to the level required by the process under consideration. The methods most widely utilized at present to this end make use of solar energy at the time of mining to reduce the water content to 30-50%. These are the well known milled peat or sod peat mining techniques, which allow the mined peat to dry on the surface of the bog before being collected and used. This peat may be further dried before processing by utilizing any waste heat which may be available from the process.

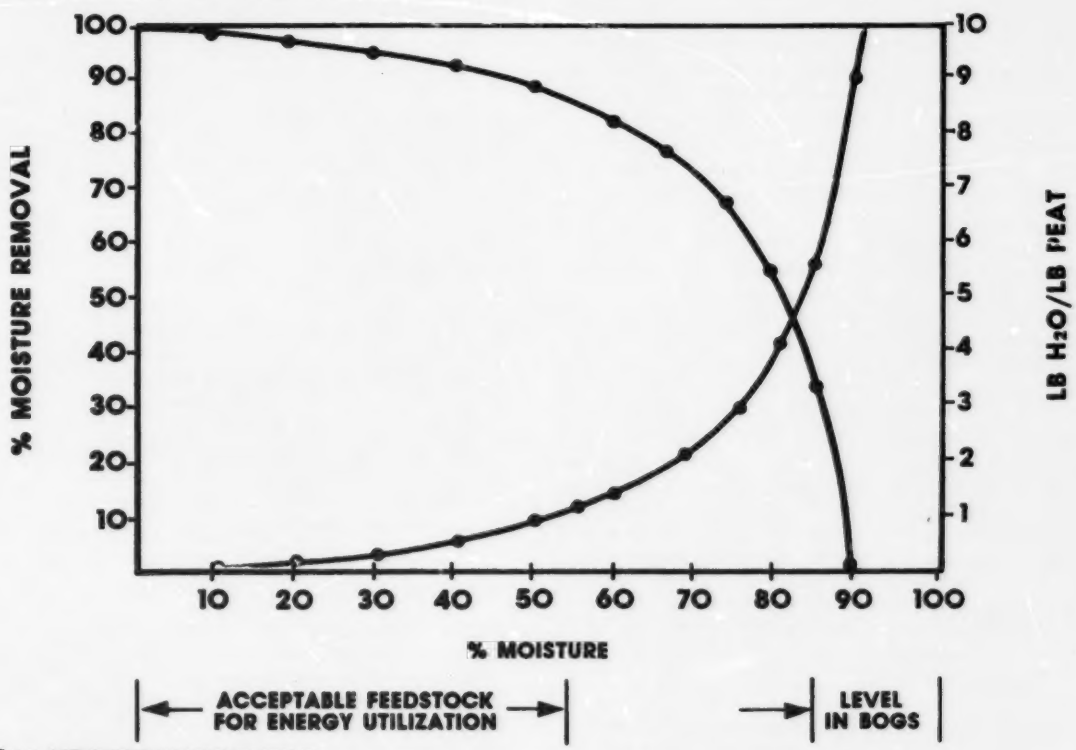


PLATE 4-1. MOISTURE LEVELS IN PEAT.

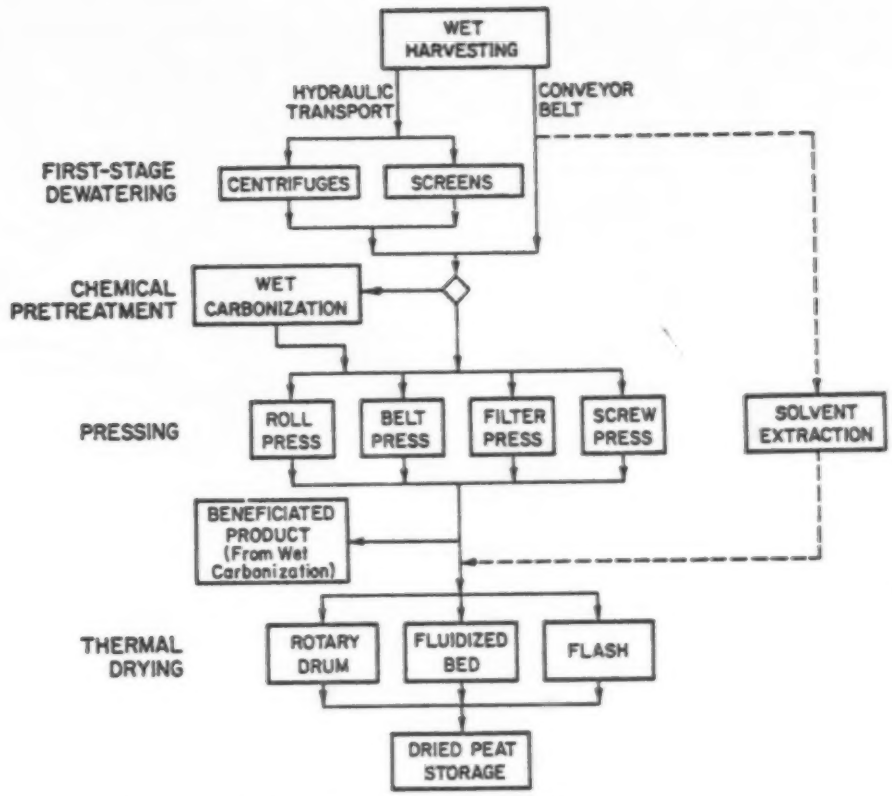


PLATE 4-2. ALTERNATIVE METHODS FOR DEWATERING PEAT.

In many situations, this is perfectly adequate. There are others, where the potential drawbacks force a look for alternatives:

- the climate of the location does not allow an economical mining season
- the scale of the proposed operation would necessitate an inordinately large area to be worked, since only a thin layer of the bog surface can be mined each season (e.g. 10 cm/yr for milled peat in many parts of Ontario)
- there are environmental problems associated with these mining methods: wind-borne dust, interruption of natural environments for long periods (20 years or more), possibility of bog fires.

Without the use of solar drying, dewatering is envisaged in two or more steps. Plate 4-2 indicates a number of different operations that have been proposed for dewatering peat. Bog material would be excavated with 80-90% moisture content and transported to the processing plant by conveyor, slurry pipeline or truck. A combination of pressing and other methods further reduce the water content to the required level. It is to be noted that several of the operations shown are not yet commercially available (solvent extraction, centrifugal beneficiation).

The technical and economic considerations of peat mining, referred to climatic conditions in Ontario, are discussed in detail in Part 3. These will yield the cost of peat at a given moisture content, specific to climatic region and scale of operation. Several alternatives are available for further reduction of water content, if required by the end use of the material. The economic evaluation of any processing-train is, therefore, quite site-specific, and requires detailed considerations of climate, scale of operation, choice of process and energy recovery.

In this part, descriptions and costs will be given for several kinds of commercially available mechanical and thermal dewatering equipment of moderate scale of application. Larger installations need to be integrated with the entire process train, to take advantage of recoverable waste heat available in the process. Concluding this part, a section will briefly mention dewatering technologies under development.

4.3.2 MECHANICAL DEWATERING

Because of peat's great affinity for water, the application of pressure in any form to reduce the water content below 65 to 70% requires so much power and time that it is not economical for commercial use. Even to reach 70% moisture, an optimized design of high production capacity and pressure is needed. Centrifuges, screens and vacuum filters are essentially low-pressure applications. They may be used to thicken thin slurries of peat from 1-3% to about 6% solids, as practised by the Western Peat Moss Co. Ltd. in Vancouver, B.C. Roller and belt presses have performance/cost characteristics adequate for commercial use. Automated semi-continuous filter presses form part of the JP-Energy and Koppelman processes. Screw presses were not found to be cost effective in the industry.

Wet mined peat enters the plant at 97 to 99% moisture or 80-90% moisture, depending on the production and transport method used. Thin slurries are thickened to 90-94% moisture before dewatering by the method selected.

4.3.2.1 THE INGERSOLL-RAND VARI-NIP® TWIN ROLL PRESS

DESCRIPTION. The Vari-Nip press consists of two perforated horizontal rolls mounted in a sealed vat. One roll is fixed, while the other is movable to allow for variable nip openings. If the mat thickness varies, the variable roll automatically follows this change and maintains a constant nip load, resulting in constant moisture in the discharged solids.

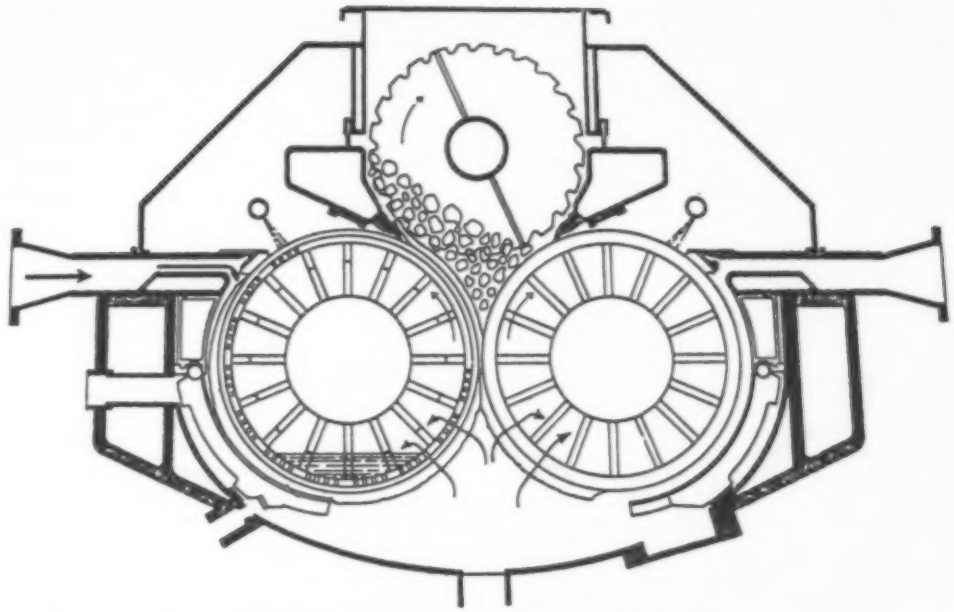


PLATE 4-3. SCHEMATIC OF INGERSOLL-RAND VARI-NIP PRESS MACHINE.

The slurry, at an incoming solids level of approximately 6% (allowable range 3-10%), enters the sealed vat by gravity feed. The slurry then drains by pressure filtration and forms a mat on the roll surfaces which is carried forward into the nip by the rotating rolls. In the nip, the mat is further dewatered to 30-35% solids.

Immediately beyond the nip, the solids are scraped off the rolls and guided into a top-mounted screw-type shredder conveyor. The dewatered material is then gravity discharged at the rear end of the machine for conveyance to ultimate disposal. The pressate flows through the roll faces and is discharged at the bottom of the press. Plate 4-3 is a schematic view of the press.

PERFORMANCE CHARACTERISTICS. The operation of the machine depends on a fibrous mat forming on the surface of each roll, through which the water drains, capturing all but 5-10% of the solids fed. The consequence of this is that the application of this equipment is limited to little-decomposed peats (von Post H1-H4), otherwise no mat is formed. Furthermore, in a feed consisting of a mixture of fibrous and colloidal particles, the fibrous material will be preferentially picked up and, in effect, classified. This characteristic is a definite advantage when the desired product is a fibrous peat (e.g. for agricultural use), but it renders the unit inapplicable to fuel-peat dewatering.

The production rate of the machine is linearly dependent on the width of the roll. Any width up to 3.5 metres may be specified. It has been found that minimum nip angle (i.e. maximum roll diameter, 900 mm) will lead to satisfactory operation.

Solids rejection depends on the humification grade: this varies from about 5% of solids fed returned to the bog at H1-2, to up to 10% at H4. Therefore, the production rate varies slightly with humification grade.

Work on the dewatering of peat from 94% to 70% moisture content indicates that, for the Vari-Nip press with 3 m × 900 mm rolls, the maximum productivity is 100 tonnes/day dry solids. Higher initial solids content would result in more production, but it is difficult to get the feed into the machine at higher solids content.

DEVELOPMENT WORK. The present version of the peat press is the result of several years' mechanical development. Current efforts are aimed at feeding peat at 90% moisture, thereby increasing production capacity.

Experiments showed that fuel peat may be dewatered to 30% solids with the addition of polyelectrolyte, but no commercial development of this finding has taken place to date.

COSTS FOR THE DESIGN EXAMPLE. Table 4-1 gives capital and operating costs for two sizes of roller presses. The cost of processing shown does not include the cost of peat feedstock.

TABLE 4-1. INGERSOLL-RAND VARI-NIP® ROLLER PRESSES.

Costs (July, 1981, 6000 hours/year)		
Size	3.0 m x 900	2 m x 900
Capital Cost:		
(304 SS construction)	$ 970,000	$ 760,000
Erection, supervision, engineering, auxiliaries @ 50%	485,000	380,000
Total installed cost:	$1,455,000	$1,140,000
Labour: 1 man/shift		
3 men @ $20,000	$ 60,000	$ 60,000
Maintenance: 3% of capital cost	30,000	22,800
Water: flow	0.36 m^3/min	0.25 m^3/min
@ $0.055/$m^3$	$ 7,120	$ 4,950
Power: consumption	37.3 kW	22.4 kW
@ $0.035/kWh	$ 7,800	$ 4,700
Direct operating cost:	$ 104,920	$ 92,450
Capital charges:		
20 yrs, 20% CRF	$ 299,000	$ 234,000
	$ 403,920	$ 326,450

Design Example		
	3.0 m x 900	2 m x 900
Humification, von Post	H1-4	H1-4
Feed moisture	94%	94%
Rejection of solids fed	7.5%	7.5%
Moist solids fed, tonnes/h	74.71	46.30
Dry solids in feed, tonnes/h	4.48	2.78
Pressed solids moisture	70%	70%
Production rate, moist, tonnes/h	13.9	8.57
Production rate, dry, tonnes/h	4.17	2.57
Water removal, tonnes/h (incl. rejection)	60.8	35.2
Dewatering costs, at 6000 h/yr:		
$/tonne dry solids	15.92	20.78
$/tonne moist solids @ 70%	4.74	6.23
$/tonne water removed	1.08	1.42

AVAILABILITY. The Vari-Nip Press is installed at Western Peat Moss Co. Ltd., Vancouver, U.C., and has been in production since 1978.

The machine is available from Canadian Ingersoll-Rand Co. Ltd., Pulp Processing Machinery Division, Montreal, Quebec.

4.3.2.2 THE SULZER MULTI-NIP® BELT PRESS

DESCRIPTION. The Sulzer Brothers' Multi-Nip press (Switzerland) is essentially a development of the double wire press principle used for mechanical dewatering in the pulp and paper industry. Peat, however, is much more difficult to dewater than cellulose, and the development program has evolved a design that incorporates the following three principal features essential to optimized performance:

- Progressive application of pressure
- Long residence time
- Specialized belt system

The Sulzer press has a large number of pairs of rollers that apply progressively increasing pressure as the peat passes through the machine. In the inlet zone, the peat is stabilized by the application of moderate pressures. This feature minimizes rejection of the peat at the nip of the rolls. In the later stages, higher pressures (approximately 4.2 MPa, 609 psi) are applied to maximize the extraction of water from the stabilized cake of peat.

The speed of operation, combined with the multiple pressure rolls, ensures a long residence time in the press zone - about 10 to 12 seconds.

The belt system consists of four belts. Two are polyester sieves between which the peat travels through the machine. Above the upper sieve belt is a resilient rubber belt, which is a key element in stabilizing the peat in the pressing zone and which allows for foreign material (<2" diameter) that might find its way into the press with the feed. Below the lower sieve belt is a harder rubber belt provided with diagonal channels in a herringbone pattern through which the water is expelled. The belts are driven by two head pulleys that are connected through reduction gearing to an electric motor. There is a variable-speed gearbox between the upper and lower head pulleys to enable the respective belts to be driven at slightly different speeds. This will turn the peat over during pressing and present different aspects of the fibers in order to achieve more effective dewatering. The whole press is mounted on a rigid hollow box section structural steel base frame that requires no special foundation or anchor. At present, a 2 m wide belt machine is available. Plate 4-4 is a schematic view of the press.

PERFORMANCE CHARACTERISTICS. The special elastomer backing-belts allow the dewatering of any humification grade of peat, with only a slight penalty in solids rejection.

Recent testing at the pilot facility in Kriens, Switzerland, gave these results on Sphagnum moss:

von Posto Index	Feed Rate 90% MC	Solids Rejection	Cake Moisture
H1-4	20tonne/h	1%	70-72%
H6-7	20tonne/h	2-3%	67-70%
H8-10	20tonne/h	3%	Not Available

TABLE 4-2. SULZER MULTI-NIP BELT PRESS.

Costs (July, 1981, 6000 hours/year)	
Total installed cost of press, including transportation, feedworks, building, erection, supervision, engineering, startup	$811,766
Labour, 2 men/shift, 6 men @ 20,000	$120,000
Maintenance, Belts, etc.	60,000
Water, 4.5 ℓ/min @ $0.055/1000 ℓ	90
Power, 150 kW @ $0.035/kWh	31,500
Direct operating cost, 6000 h/yr	$211,590
Amortization, 20 yrs, 20% CRF	$166,700
Annual operating cost	$378,290

Design Example			
Humification, von Post	H1-4	H1-4	H6-7
Feed moisture	90%	80%	90%
Rejection of solids fed	1%	1%	3%
Moist solids fed, tonnes/h	20	20	20
Dry solids in feed, tonnes/h	2	4	2
Pressed solids moisture	70%	70%	68%
Production rate, moist, tonnes/h	6.60	13.2	6.06
Production rate, dry, tonnes/h	1.99	3.96	1.97
Water removal, tonnes/h (incl. rejection)	13.40	6.80	13.94
Dewatering costs, at 6000 h/yr:			
$/tonne dry solids	31.32	15.73	31.64
$/tonne moist product	9.44	4.72	10.28
$/tonne water removed	4.65	9.16	4.47

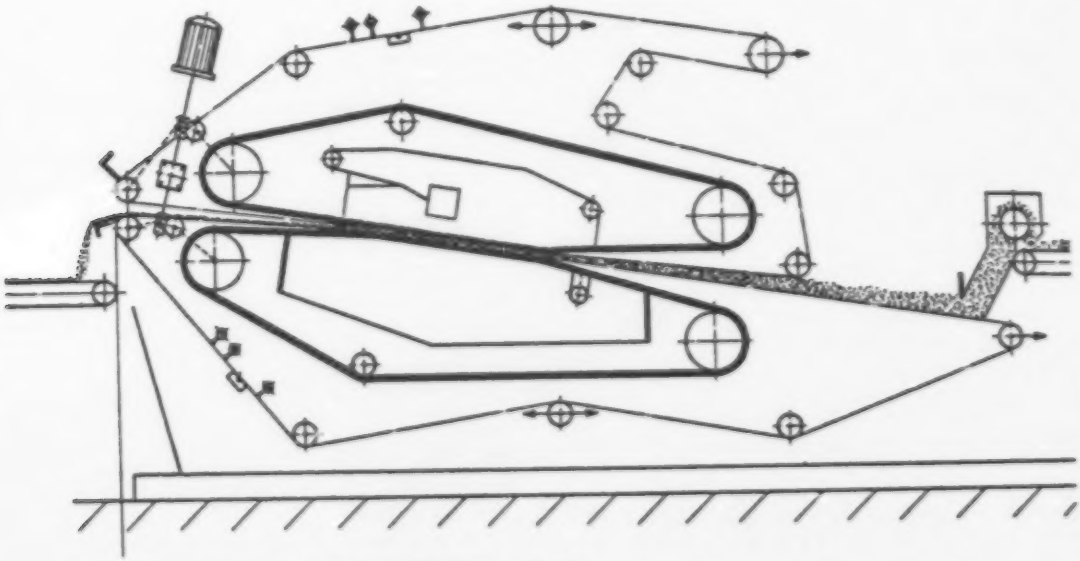


PLATE 4-4. SULZER MECHANICAL DEWATERING BELT PRESS.

Tests are continuing with reed-sedge peat. The company advises pilot testing of peat samples on their 1 m wide demonstration unit, before detailed plant design is carried out.

The moist peat feed rate is determined by the belt velocity and is independent of initial moisture. The final cake moisture is likely to improve somewhat with more concentrated feed, but this needs confirmation. The dewatered solids production is roughly proportional to the feed solids content. Such a case was calculated in the design example (Table 4-2), based on this expectation.

A notable feature of this equipment is that, according to the manufacturer, it is capable of dewatering even highly humified peats.

DEVELOPMENT WORK. Data collection is continuing at the experimental facility at Kriens, Switzerland, to collect extensive performance results on a variety of peat samples. It was recently learned that a design modification achieved 62% moisture content on a Minnesota peat sample supplied by IGT. If this is confirmed, the implications of this result to dewatering economics are quite substantial.

COSTS FOR THE DESIGN EXAMPLE. Capital and operating costs are given in Table 4-2.

AVAILABILITY. A Multi-Nip belt press has been operating since 1978 at a horticultural peat producer's bog near Bad Zwischenahn, West Germany. The design is considered to be fully commercial, and the press is available in Canada from International Peatco Ltd., Chilliwack, B.C.

4.3.3 THERMAL DRYERS

If the wet mined peat is not subjected to "wet carbonization" treatment (as in the JP-Energy process), it cannot be mechanically dewatered to less than 65% moisture content. Although 62% of the original 90% moisture content (56.7 kg of 90 kg) has been removed mechanically, over 2 kg of water remains per kilogram of dry peat, half of which must be removed before efficient combustion can be contemplated at 50% moisture or below. For coking or briquetting, the feed moisture content must be 30% or 15% respectively.

In all processes discussed in later sections, the drying operation has been integrated in the process design in order to take advantage of waste heat sources to improve overall thermal efficiency. The discussion below describes the general features of thermal dryers and gives a specific example of a gas-fired dryer.

There are three thermal dewatering methods available to effect further drying:

- rotary drum
- pneumatic conveyor (flash)
- fluidized bed.

All three technologies are well known, although applying them to peat drying may involve special know-how in the design of materials handling systems and to minimise the danger of dust explosions. Experienced designers of peat dryers are: M-E-C Company (Neodesha, Kan.), Heil Inc. (Milwaukee, Wis.), and Ahlström OY (Varkaus, Finland), for rotary and flash dryers, Outokumpu OY (Espoo, Finland) for flash dryers, Escher-Wyss GmbH (Zürich, Switzerland) for specialized fluidized bed dryers.

Which of the three drying methods are used will largely depend on:

(a) the final use of the dried peat,

(b) size of the installation, and

(c) the availability of waste-heat from other parts of the process-train.

The final choice will be made on the basis of economic evaluation of otherwise equivalent methods. Any of the three methods may be controlled to yield any desired final moisture content. None are limited by the degree of humification of the peat.

The following general observations apply:

- A direct dryer consumes more fuel per unit of water evaporated, the lower the final moisture content
- Efficiency increases with an increase in the inlet gas temperature, for constant exhaust temperature.

It must be emphasized that each proposed application needs to be individually evaluated, especially from the point of view of utilizing any waste-heat sources in the total system, such as flue gases or low-pressure steam.

4.3.3.1 ROTARY DRUM DRYERS

This is the method of choice, when air-dried sods are further dried from 45% to 10-15% moisture, prior to the preparation of low-density peat coke. The rate of drying can be so adjusted that the peat pieces are not subject to cracking and attrition. The danger of dust explosion limits designs to the co-current flow arrangement. Operating cost is similar to flash dryers on comparable service. Purchase cost is comparable to flash dryers, although space economies may give the latter a slight advantage. Thermal efficiency is also similar to flash dryers: 55-75% based on water vaporized to fuel burned. It is possible to use waste heat to reduce or eliminate auxiliary fuel, thereby improving overall process thermal efficency.

Rotary dryers are shop-fabricated; therefore, there is a limit to the size that can be shipped by rail (4.2 m [13.5 ft] diameter maximum in U.S.). This consideration may also weigh against their selection for remote locations. The source of heat may be flue gases from boiler or coking oven, or a combustion unit burning peat fines, waste wood, natural gas or oil. Exhaust gases are passed through cyclones for the collection of fine particles, and finally a venturi scrubber before exhaust to the atmosphere.

A design example with capital and operating costs will be given below for two sizes of commercially available drum dryers (Table 4-3).

TABLE 4-3. HEIL ROTARY DRUM DRYER (GAS FIRED).

Costs (July, 1981, 6000 hours/year)		
Type	SD105-32	SD105-42
Evaporation capacity, tonnes/h water	8.2	16.4
Capital cost, dryer, burner (stainless steel)	$362,949	$ 606,604
Installation, shipping, building, engineering	202,514	360,920
Venturi scrubber, separator, fan, stack	91,050	139,100
Installation @ 30%	27,300	41,730
Total installed cost	$683,813	$1,148,354
Labour, 1 man/shift 3 men @ $20,000	$ 60,000	$ 60,000
Maintenance, 3% of capital cost	20,514	34,451
Power consumption (incl. auxiliaries)	120 kW	150 kW
Power cost @ $0.035/kWh	25,000	31,500
Gas fuel, 3.85 MJ/kg water, $3.10/GJ	580,250	1,162,500
Direct operating cost	$686,764	$1,288,451
Amortization, 20 yrs, 20% CRF	$140,453	$ 235,872
Annual operating cost	$827,219	$1,524,323

Design Example		
Type	SD105-32	SD105-42
Feed moisture	70%	70%
Moist solids feed, tonnes/h	20.5	41
Product moisture	50%	50%
Evaporation capacity, tonnes water/h	8.2	16.4
Production @ 50% final moisture, tonnes/h	12.3	24.6
Dry solids processed, tonnes/h	6.15	12.3
Drying costs, at 6000 h/yr		
$/tonne dry solids	22.32	20.57
$/tonne moist product, @ 50% MC	11.16	10.26
$/tonne water removed	16.74	15.43

4.3.3.2 FLASH DRYERS

They have been found suitable for drying both horticultural and fuel peats. They are not suitable for drying sods without prior crushing. Much more comminution occurs in the flash dryer than in either rotary or fluidized bed dryers, due to the high velocity and turbulence of the gas flow which occurs within the pneumatic conveyor dryer. However, the fines can be collected in multiple cyclones and briquetted, as in the Outokumpu peat briquette plant.

Thermal efficiency is comparable to a co-current rotary drum dryer on similar service. When used in combination with a boiler, the use of flue gases for drying can provide very high combined efficiency: Ahlström OY quotes 89%. Western Peat Moss' flash dryer uses 3.1 MJ/kg H_2O when drying from 75 to 55% moisture. The efficiency would drop as the product moisture content decreased.

Flash dryers are field-assembled units, components may come from several suppliers. Therefore, there appears to be no obstacle to assembling large units.

Operating and purchase costs are said to be similar to those of rotary drum dryers, although space economy available with flash dryers may give them the advantage in otherwise comparable applications. Flash dryers form part of two process trains which will be discussed in detail in later chapters.

4.3.3.3 FLUIDIZED BED DRYERS

On account of the lumpy nature of the mechanically dewatered peat cake, fluidized bed dryers need to be of the "vibrating conveyor bed" configuration. Such equipment is available specifically for peat, from Escher-Wyss of Switzerland, marketed as part of the Sulzer Peat Dewatering system, by International Peatco.

Fluidized bed drying has these advantages over the other two technologies:

- minimum thermal degradation. This may be a requirement for high-grade horticultural peat or special products,
- minimum comminution of particles,
- possibility of using low-grade steam in heat exchanger coils inside the fluid bed, and
- possibility of classifying product into a coarse and fine fraction.

It appears that operating power requirements are higher for this type of dryer than for the other two types as would be the capital cost.

4.3.3.4 DESIGN EXAMPLE - HEIL ROTARY DRUM DRYERS

DESCRIPTION. The equipment package costed in the Design Example (Table 4-3) consists of a three-pass co-current drum dryer, with gas-fired heater, fans, drum drive, venturi scrubber and collector, stack and building enclosure. Allowances have also been made for installation cost, engineering and startup.

A peat-fired burner will also be available in the near future, as well as one for oil fuel. Accurate cost estimation requires details of the proposed installation.

PERFORMANCE CHARACTERISTICS. The amount of water to be evaporated is the main design parameter. Within this specification, the feed and product moisture contents can be rather closely controlled. The danger of dust explosion limits the final moisture content to about 15%. Thermal efficiency is given by the manufacturer as 3.85 MJ/kg water evaporated, or 1666 Btu/lb water.

DEVELOPMENT WORK. The design parameters are well known and the performance is predictable. The equipment is considered to be fully developed.

COSTS FOR THE DESIGN EXAMPLE. Capital and operating costs for two sizes of gas-fired rotary drum dryers are given in Table 4-3. The drying cost shown does not include the cost of feedstock or prior mechanical dewatering.

AVAILABILITY. Six installations are known to exist in Western Canada which are drying peat. The dryers are manufactured by Heil Inc. of Milwaukee, Wis., and marketed in Canada by International Peatco, Chilliwack, B.C.

4.3.4 REVIEW OF DEVELOPING DEWATERING TECHNOLOGY

It is appreciated by anyone working with peat that the greatest obstacle to its widespread utilization is the cost of separating it from water. Attempts to accomplish this have been under way for at least a hundred years. Although it is obvious by now that no radically cheaper solution is likely to be forthcoming, the experimental work briefly described below may lead to marginal improvements to process economics in the future.

4.3.4.1 SOLVENT EXTRACTION DEWATERING

The Institute of Gas Technology (IGT) is working on a solvent-extraction type of peat dewatering process under the sponsorship of the U.S. Department of Energy and Minnegasco. This process uses the principle that, in certain solvents, the solubility of water changes significantly with a change in temperature — in other words, higher solubility of water at higher temperatures and lower solubility at lower temperatures.

In this process, wet peat is contacted with the solvent at high temperature. Water accompanying the peat dissolves in the solvent, the solvent is decanted and allowed to cool. When the solvent-water mixture is cooled, the solubility of the water in the solvent decreases, and the mixture separates into two layers: a water-rich layer and a solvent-rich layer. The water-rich layer is sent to a solvent recovery system before discharging the water to the bog or other reservoir. The solvent, containing a small percentage of water, is returned to be mixed with fresh peat. Solvent remaining with the peat and its retained water is evaporated in a dryer prior to peat processing. Vaporized solvent is recovered from the dryer flue-gas, separated from the water condensate and reused.

Initial laboratory tests have been successful and will be followed by larger scale experiments.

4.3.4.2 MULTIBELT PRESS

A different approach to belt-press dewatering is taken by Axel Johnson Engineering, AB, of Nyneshamn, Sweden. Instead of a multitude of roll-nips, as in the Sulzer press, their approach is to provide gradually increasing pressure at the feed end of the unit by two belts approaching at an acute angle. This is followed by a low-pressure stage, where additional water is expressed. The high (2 MPa, 290 psi) pressure required for peat dewatering is achieved in the high-pressure section, where a number of parallel V-belts wrap themselves around the travelling belt-sandwich and press them, with the peat between, against a perforated drum. This approach claims savings in reduced belt-wear, since the pressure is not achieved by tensioning the belts, and cheaper construction, since the reaction forces requiring heavy-duty construction, are isolated in the high-pressure section of the machine.

Tests have been done on a pilot press and they were sufficiently encouraging so that a 1 m wide demonstration machine is under construction now. This will be installed at a bog near Stockholm to start experiments in the Fall of 1981. After incorporating the expected improvements into the design, demonstration runs will commence during Spring, 1982.

Projected prices quoted in the course of a visit to Axel Johnson AB indicate that the Multibelt press should cost about one-third of the price of the Sulzer press.

4.3.4.3 CENTRIFUGAL CLASSIFICATION OF PEAT

It has been proposed by Lindstrom *et al.* (1978, 1980) that, if the colloidal fraction of the freshly mined peat slurry is removed by some means (e.g. centrifugation), the resulting, slightly thickened (to 15-17% solids) slurry can be more easily dewatered mechanically, and there is an overall saving of dewatering and drying costs. Meaningful experimental work has been hampered by the fact that peat samples were only available from a partially drained bog.

The Swedish Energy Development Corporation is considering the sponsorship of pilot work, which should take about one year. Following that, bogside process demonstration will proceed with funds provided by the Swedish Railway Corporation.

4.3.4.4 WET CARBONIZATION

This process concept consists of heating a peat-water slurry in a closed reactor at 200°C and 2.5 MPa (370 psi). The resulting chemical changes render the peat mechanically dewaterable to about 50% moisture by conventional means. The heating value of the treated material is increased by some 20% on a dry basis. This reaction forms the basis of the Finnish JP-Energy process, and it is discussed in detail in the next chapter. Mensinger (1980) has reviewed past and present efforts to develop this process on a commercial scale.

4.3.4.5 WET OXIDATION

Wet oxidation is combustion in the presence of water. It is an established technology for the oxidation of many organic materials and industrial wastes. Oxygen or air is supplied at high pressure to raw peat in a heated, stirred vessel under pressure. Combustion is rapid, controlled by the rate of oxygen supply.

This process may be carried to completion to produce energy or stopped when it has generated enough heat to effect wet carbonization of the remaining peat, which can be dewatered to < 50% moisture by pressing.

The Ontario Research Foundation is currently engaged in researching both of these processes under the sponsorship of Canada Energy, Mines and Resources. The pilot study is scheduled for completion in March, 1982. Results of total wet oxidation experiments and projected economics will be presented at the International Peat Society meeting in Thunder Bay, Ontario, October, 1981.

4.4 PEAT BENEFICIATION

4.4.1 GENERAL

Beneficiation processes enhance the quality of a low-grade fuel by increasing its ease of handling, its heating value and, in the case of peat, increasing its dewaterability. To serve these ends, four technologies are available:

- drying and briquetting of milled peat, yielding an easy-to-handle, dense fuel of low (10-15%) moisture content,
- drying and coking sod peat, resulting in a premium product, suitable for electro-metallurgical applications or as a substitute for charcoal in chemical processing,
- wet carbonization of wet-mined peat resulting in easier dewatering and improved heating value, and
- wet pyrolysis of wet mined peat, yielding a much improved, pelletized fuel.

These technologies will be discussed in the form of integrated process-trains, with mined peat of the appropriate form entering the plant and finished product leaving the other end.

4.4.2 INTEGRATED PEAT DRYING AND BRIQUETTING FACTORY

The briquetting plant under discussion here is an example of integrated peat process design. The plant is fuelled by burning a portion of the peat in a fluidized bed burner to provide energy for drying the peat to the required moisture level.

4.4.2.1 CURRENT STATE OF DEVELOPMENT

Outokumpu OY of Espoo, Finland, has built two plants in recent years for VAPO, the State Fuel Centre of Finland. One forms part of a sod peat coking plant located near Peraseinajoki, the other one is in Ilomantsi, operating on milled peat feed. A third unit is under design for VAPO. Therefore, the technology and equipment may be considered fully developed.

The Company will undertake feasibility estimates or turnkey design and construction assignments in co-operation with Canadian engineering and construction firms. The plant discussed here has an annual capacity of 50,000 tonnes of briquettes, based on 7000 hours per year of operation. This is the maximum design capacity contemplated at this time. The exponential scaling factor for capital cost extrapolation is 0.5, according to Outokumpu. The anticipated period from start of design to plant startup is 18 months.

4.4.2.2 FEED CHARACTERISTICS

The Ilomantsi plant is fed milled peat at 40-55% moisture, transported from the bog by specially designed trucks. The plant can operate on moderately low humified peat, but the fuel value of the feed materials affects the heating value of the product and the thermal balance of the plant: if H2-4 peat is used, the process needs auxiliary oil or natural gas fuel. Therefore, fuel peat, > H5, is the preferred feedstock.

4.4.2.3 PRODUCT CHARACTERISTICS

Briquettes consist of dried and compressed peat, without any chemical transformations having taken place, nor is there any binder added. Therefore, the ash and sulfur contents are comparable to those of the starting material on a dry weight basis. Residual moisture content is between 12-15%. The heating value ranges from 18.5 to 20.8 MJ/kg (8000-9000 Btu/lb), depending on the heating value of the feed material, its ash and moisture content. The bulk density is 700 kg/m^3 loose, 1000 kg/m^3 stacked. The specific gravity is 1.2 g/cm^3 .

The fuel burns with a smokeless flame and has very low sulfur emission. Therefore, it is environmentally acceptable for household use. It is sold for FMK 500/tonne, wholesale (C$1 = FMK 3.6). In Scandinavia, it is marketed in 5 and 10 kg plastic-wrapped packages in gas-stations and grocery stores.

There is about 1.5 MW thermal energy by-product available as 70°C hot water, recovered by indirect heat exchange from scrubber water. In Finland, this is adequate for heating 3600 m^2 of greenhouse area in the winter.

4.4.2.4 PROCESS DESCRIPTION

The mined milled peat (40-55% moisture) is transported to the plant from the bog. To produce briquettes of good mechanical strength, it is necessary to use peat of homogenous particle size, humification grade and moisture content. Therefore, impurities are removed at a screening station, and the screened peat is conveyed to a combined storage and homogenizing bunker, which is similar to the equipment for peat-fuelled power stations.

During the filling of the homogenizing station, a row of carriage mounted rotating screws, operating transversely, mixes up and moves the peat to the discharge end of the bunker. The blended peat is transferred to the feed bins of the processing equipment.

Equipment for drying and combustion of milled peat comprises a flash dryer and a 7 MW* fluidized bed combustion unit. The gas required for drying is heated by burning 12-15% of the peat in the fluid bed burner. The combustion gas is blended with warm stack gases to the temperature appropriate for the dryer (600°C).

The peat to be dried is fed into the lower part of the drying section, where it is entrained by the gas circulating at 6-10 m/s. The dryer duct diameter is 1 metre for 50,000 TPY; this is considered to be the minimum economical size. The maximum size dryer considered practical at this time is 2 metre diameter, for four times the production capacity.

Most of the dried peat is separated in a cyclone, the exhaust gas is further cleaned in a series of small cyclones and a venturi scrubber. The separated dry peat is taken to the feed conveyor of the presses and the exhaust gas from the scrubber is led to the stack. The dried (12-15% moisture) peat is pressed, without any binding material, by twin briquetting presses (Buckau-Wolf, Germany) into solid forms. The conceptual flowsheet is illustrated in Plate 4-5.

The Peraseinajoki plant is of a different configuration, as it forms part of a coking process. It will be described in the next section.

4.4.2.5 MASS AND ENERGY BALANCE

Up to 15% of the peat delivered to the plant is used for generating 7 MW of heat to dry the peat from 40-55% moisture to about 15%. The electrical consumption is estimated to be 1.5 MW. There is approximately 1.5 MW of waste heat available as 70°C water, recovered through heat exchange from the scrubber water. The overall thermal efficiency of the plant, considering the above figures, is 76%.

4.4.2.6 CAPITAL, OPERATING AND PRODUCT COSTS

Cost estimates are given in Table 4-4. Capital and operating costs were estimated by Outokumpu OY. Feed peat costs were derived by Monenco Ltd. as part of this study.

The capital cost includes complete grassroots installation with civil works within battery limits. The product costs do not include any royalties for peat or process.

4.4.2.7 ENVIRONMENTAL CONSIDERATIONS

Little wastewater is discharged from the plant. The scrubber liquor is recirculated after separating the solids in a settling pond. Once a year, the pond is drained and the settled solids are removed. These and the small amount of ash produced (less than 175 tonnes/yr) need to be disposed of. No figures are available for air emissions from the combustion/dryer unit. Open-air handling of milled peat is likely to cause a dust emission problem.

4.4.2.8 ASSESSMENT

The plant is based on well known unit operations. Material handling is always a problem with milled peat, but the difficulties have been largely overcome through experience and the design of suitable equipment (Solantauste and Asplund, 1980).

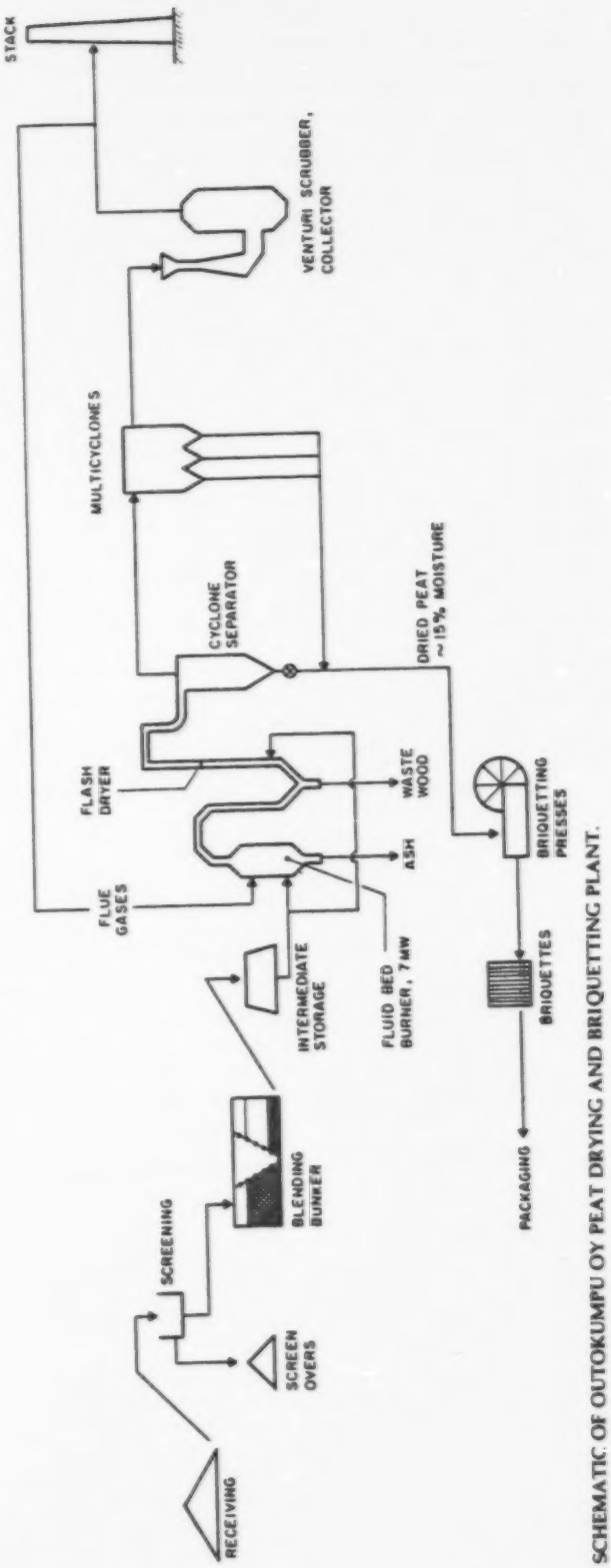


PLATE 4-5. SCHEMATIC OF OUTOKUMPU OY PEAT DRYING AND BRIQUETTING PLANT.

* For the 50,000 TPY plant, Ilomantsi.

4.4.3 PEAT COKING AND BRIQUETTING FACTORY

Peat coke is produced by the carbonization of field-dried peat sods of well humified Sphagnum peat. The main industrial uses of peat coke are as reductant in metallurgical processes or starting material for the preparation of activated carbon.

Two technologies for the production of peat-coke are practised at this time: Karl Still GmbH of Germany uses a vertical coking reactor configuration, whereas Outokumpu OY of Finland has designed an integrated sod drying and coking facility employing a horizontal rotating coking kiln. Both of these technologies are available for licencing. However, at the time of writing (mid-1981), details were available only about the latter process. Technical details about peat coking are available in a review paper by Naucke (1978). Laukkanen (1979) has published details pertaining to the Outokumpu process.

TABLE 4-4. PEAT DRYING AND BRIQUETTING PLANT.

Cost Estimates			
Based on data from Outokumpu OY			
Capital Cost June, 1981			
Scaling factor: 0.5			
Battery limits, turnkey costs:			$11,700,000
Working Capital – 1 mo product			
1 mo acc. rec.			
2 wks payroll			1,120,000
Startup: 3% Total installed cost (TIC)			351,000
Total Capital			$13,171,000
Operating Cost: 7000 hours/yr			
Feed: 50,000 tons/yr briquettes at 10% moisture, + 15% peat for thermal energy = 51,750 dry tonnes/year			
Milled peat in Central Ontario, incl. 10 miles haulage: $24.5/tonne at 50% moisture			
$49/dry tonne, @ 10,000 Btu/lb			$ 2,535,800
Labour: 4 operators/shift, 4 shifts:	16		
2 maintenance:	2		
5 administrative:	5		
4 mat'l. handling/shift:	16	39 men	
at $30,000/yr:			$ 1,170,000
Utilities: 1.5 MW x 7000 hours x $0.035/kWh			$ 370,000
Maintenance: 3% of TIC:			$ 360,000
Total Direct Production Cost:			$ 4,435,800
Per tonne of product:			$88.71
Per MBtu (@ 9000/lb)			$ 4.48
Per MJ (@ 18.9/kg)			$ 4.27
Capital Charges: 20 yr, 20% CRF			
Total investment x 0.2 p.a.			$ 2,705,100
Per tonne of product:			$54.10
Per MBtu:			$ 2.73
Per MJ:			$ 2.60
Total Product Cost:			$142.81/tonne
			$7.21
			$6.86/MJ

4.4.3.1 CURRENT STATE OF DEVELOPMENT

The State Fuel Center of Finland (VAPO) has built a peat utilization complex using Outokumpu OY's peat coking process near the village of Peraseinajoki. The complex includes a peat coking plant and a peat briquetting plant with a production of 30,000 tonnes of both peat coke and briquettes per year. The power plant integrated with the factory generates 12 MW of electricity and 20 MW of thermal power for the heating of twenty 2400 m^2 area greenhouses. 9 MW of electrical power is available for sale beyond the 3 MW used in the plant.

The coking plant was started up in September, 1976. Problems were initially encountered with pulsating flow in the air circulating system, the choice of erosion resistant materials in the waste-heat boiler and at the inlet of the coking drum, and the selection of raw material and processing conditions for the production of strong, high-quality coke. These problems have been overcome, and Outokumpu OY now offers turnkey design and construction services in co-operation with Canadian engineering and construction firms.

The exponential scaleup factor is estimated by Outokumpu OY to be 0.7. The anticipated period from the start of design to plant startup is 24-30 months.

4.4.3.2 FEED CHARACTERISTICS

The quality of the coke produced is strongly dependent on the characteristics of the feed: sod peat size, its strength (dependent on the harvesting machinery used and the humification grade), heating value and chemical composition will all influence the specifications and eventual value of the product (Naucke, 1978).

Humification grades as low as H5 may be used, but, for best results, H7 or higher is recommended. The Finnish-style sod peat machine equipped with 5 cm diameter nozzles was found to produce appropriately sized sods. These are field-dried and trucked to the plant at 35-40% moisture content. It is a further requirement for producing metallurgical cokes that the feed have low ash (<3%), sulfur (<0.3%) and phosphorus (<0.2%) contents.

4.4.3.3 PRODUCT CHARACTERISTICS

Two kinds of cokes are produced at this plant, distinguished by their volatile-matter contents: high-volatile (12-14%) coke for household use as BBQ fuel and possible starting material for activated carbon manufacturing, and low-volatile (2-4%) coke for use in metallurgical applications.

The particle size (and mechanical strength) of the coke is an important determinant of selling price for metallurgical coke: the VAPO plant screens their product into <5 mm and 5-30 mm sizes, the coarser grain selling for FMK 7-800/tonne, the fines for FMK 600/tonne. The moisture content of the product is 2-4%.

Peat coke differs from coal-coke in that it is about twice as reactive, more porous and has lower sulfur, phosphorus and ash content. It also has a higher electrical resistance, which is an advantage in electro-metallurgical process applications. The use of peat coke is limited by its lower mechanical strength and smaller lump-size compared to coal-coke.

Specifications of Finnish peat coke, on a moisture free basis are:

Volatile matter	2-4%	12-14%
Carbon	90-93%	80-85%
Ash	3-8%	3-8%
Sulfur	0.1-0.2%	0.1-0.2%
Phosphorus	0.03-0.1%	0.03-0.1%
Iron	0.5-0.8%	0.5-0.8%
Heating value	~ 31 MJ/kg	~ 31 MJ/kg

The briquettes are co-produced from the fine screenings and are similar to those previously described.

4.4.3.4 PROCESS DESCRIPTION (after Laukkanen, 1979)

The raw material for peat coke - sod peat with a grain size of 50 mm (2") - is taken by trucks to storage bins from where it is fed into screening equipment. Fine particles are used as raw material for peat briquettes and coarse particles are transported by belt conveyors into feed bins and further to a rotary dryer.

Sod peat is dried to a moisture of 10-15% using combustion gases from the coking process. During coking,

the peat pieces shrink to a great extent. To prevent cracking, it is necessary that the initial drying process be performed slowly, at temperatures of 150-350°C (302-663°F) in a continuous co-current rotary dryer.

The efficiency of this equipment has been improved in the mid-section and mixing zones. The drum is divided lengthwise into sections in order to balance the filling ratio. Feed to the middle section is made by adjustable lifting ladles.

At the discharge end of the rotary dryer, there is a screen to remove fine peat dust which is used as raw material for briquette production in the plant. The dried peat is transferred to the coking kiln by belt conveyors.

In the Outokumpu method, dried peat sods are fed into a refractory lined, counter-current coking kiln. The heat for coking is produced by a peat dust burner as well as by the partial oxidation of pyrolysis gases in the kiln. The burner operates with oil when starting the process. During normal operation, a portion of the peat dust is taken from the drying circuit to provide part of the fuel for the burner.

Most of the heat needed in the coking process is produced by burning part of the volatiles by blowing additional air into the kiln. Feed of additional air is made at the discharge end of the kiln. Gases developed in the coking stage contain carbon dioxide and steam. Under certain circumstances, these compounds react with coke. However, loss reactions are small, mainly because of the protective envelope of gas which develops between the solid material and the gas.

For this reason, the amount of coke produced is comparable to recoveries from indirectly heated processes (e.g. Karl Still). In the rotary kiln coking process, the temperature profile of the kiln can be regulated rapidly and within wide limits by changing the amount of secondary air to the kiln and/or auxiliary burners.

The retention time of material in the kiln can be regulated within wide limits. Thus, products of different type and quality can be manufactured and various peat qualities can be used without stopping the process. Coking gases are burned in an after-burning chamber beyond the kiln. The coke is cooled in a separate cooling drum and finally screened into various grain sizes. The conceptual flowsheet is illustrated in Plate 4-6.

The coking kiln and the whole process are started by oil. During normal operation, the oil to the auxiliary burner will be replaced with dry peat dust from the drying circuit. Gases from the coking kiln are burned in the after-burning chamber.

Ash produced in the burner flows to the lower part of the chamber where it is melted, removed and granulated. Hot gases are cooled to ~ 350°C in a waste heat boiler from where they are led into the rotary dryer of sod peat. Coarse dust is mechanically separated from dryer gases by a cyclone and a venturi scrubber. Steam from the waste heat boiler in the coking unit can be used either directly for heating purposes or for power generation.

The factory operates 6-7000 hours/year, with two scheduled shutdown periods. The plant employs 100 people, including 10 administrative personnel and about 50 people in materials handling.

4.4.3.5 MASS AND ENERGY BALANCE

The plant produces 30,000 tonnes/yr of coke at 2-5% moisture and 30,000 tonnes/yr of briquettes at 12-15% moisture. This requires a feed-rate of 185,710 tonnes/yr of sod peat at 35% moisture, which results in 45% overall dry solids recovery.

The waste-heat and electricity production depends on whether the turbine is operated in the backpressure mode (10 MW electrical, 24 MW thermal) or the condensing mode (12 MW electrical, 20 MW thermal). This feature allows some matching of seasonal thermal energy demand. The plant itself uses 3 MW electrical and 2 MW thermal power which is subtracted from that produced for sale in normal operation.

4.4.3.6 CAPITAL, OPERATING AND PRODUCTION COSTS

Feedstock cost is taken from Table 3-8. The allocation of product costs was based on product prices achieveable in Ontario (electrical and thermal energy) and the cost of production of briquettes by an alternative route described in the previous section. The remainder of the production cost was charged to coke. Table 4-5 shows the detailed analysis. See also Part 5 for market analysis.

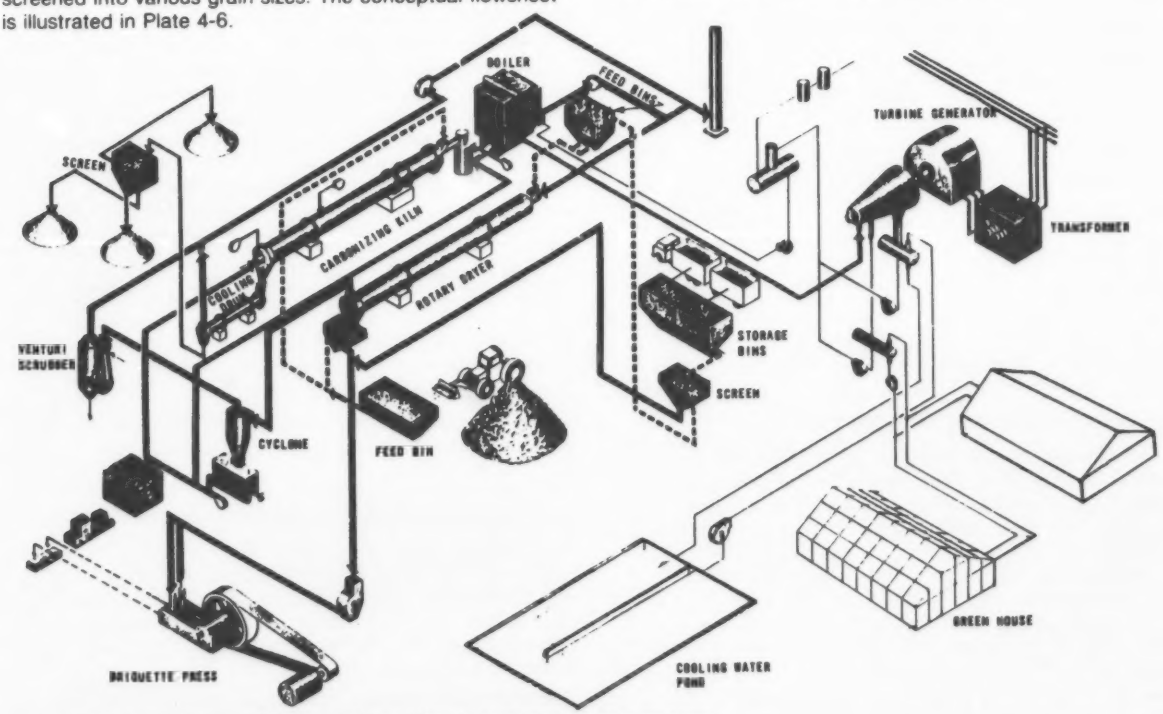


PLATE 4-6. SCHEMATIC OF HIGH GRADE METALLURGICAL COKE PLANT.

TABLE 4-5. PEAT COKING AND BRIQUETTING PLANT.

Cost Estimates Based on data from Outokumpu OY	
Capital Cost: June, 1981	
Scaling factor: 0.7	
Battery limits, turnkey costs:	$30,000,000
Working Capital: 1 month product	
1 month acc. rec.	
2 wks payroll	$ 1,830,000
Startup: 5% TIC	$ 1,500,000
Total investment	$33,330,000
Operating Cost: 7000 hours/yr	
Feed: 185,710 tonnes/year sods at 35% moisture:	
incl. 20 miles haulage: $35/tonne	$ 6,500,000
Labour: 100 men @ $30,000/yr	$ 3,000,000
Utilities: self sufficient	
Maintenance: 3% of TIC	$ 900,000
Total Direct Production Cost	$10,400,000
Capital Charges: 20 yr, 20% CRF	
Total investment x 0.2 p.a.	$ 6,846,000
Total Production Cost	$17,246,000
Products, cost allocation	
Electricity, 6.3 x 10^4 MWh @ $0.035/kWh	$ 2,205,000
District heating, 1.4 x 10^5 MWh	
@ $7.62/GJ, $0.223/kWh	$ 3,122,000
Briquettes, 30,000 tonnes/yr @ $140/tonne	$ 4,200,000
Coke, 30,000 tonnes/yr @ $257/tonne	$ 7,719,000

4.4.3.7 ENVIRONMENTAL CONSIDERATIONS

The process itself gives rise to a negligible amount of pollution. The scrubber-water is recirculated and allowed to settle in a lagoon, which is drained and cleaned annually. Solid waste is produced in the form of ash. The efficiency of the venturi scrubber cleaning stack-gases is not known.

A major pollution problem exists at the material-handling section of the Peraseinajoki plant: the open-air loading and handling of peat and coke gives rise to a large amount of flying dust. This is not only noxious, but a definite safety hazard.

4.4.3.8 ASSESSMENT

Initial problems with the equipment and the feed material appear to have been overcome and Outokumpu now offers the technology on a turnkey basis. Whether the coke can be sold at $257/tonne is questionable. To render the process profitable in a Canadian environment, additional cost reduction measures should be taken at the feasibility study stage: some 2.2 million dollars need to be saved in the annual production cost to allow the coke to be sold at $180/tonne. It will also be necessary to develop markets for the coke which will recognize its unique character and pay a premium over the price of coal-derived coke (about $150/tonne for coal-coke).

The quality and yield of the product is also sensitive to the physical and chemical characteristics of the feed material, which must be taken into consideration at time of detailed process evaluation.

4.4.4 JP-ENERGY OY WET CARBONIZATION PROCESS

To improve the mechanical dewaterability of peat, the principle of the wet carbonization process has been suggested before World War 1. In this process, wet peat slurry (from wet-harvesting methods) is heated under pressure at temperatures and residence times sufficiently severe (minimum 200°C at 2.5 MPa) to disrupt the colloidal structure of peat. Oxygen is released in the form of CO_2 and water. Disruption of the hydrophilic nature of the peat facilitates dewatering; reduction in the oxygen content (with a small loss of carbon and hydrogen) enhances the heating value. The many past attempts at commercializing this process have been reviewed elsewhere (Mensinger, 1980).

The latest approach to successful commercialization of this concept has been developed by Prof. Bertel Myreen of Turku University, Finland, who has drawn upon the results of several years' pilot plant experimentation by the Swedish Peat Company, as well as his own experience of some 800 hours of operating a nominal 20,000 tonnes/yr pilot plant. His improvements to the process promise to solve the problems that plagued previous attempts: the fouling of heat exchanger surfaces may be overcome by novel mechanical designs and the limiting of the peat slurry temperature to 65°C in indirect heat exchangers; the higher present-day value of the energy produced allows the use of corrosion-resistant materials; and the careful attention given to heat recovery in the total process also enhances its potential for success. It is claimed that the problem of waste water treatment has been eliminated through a combination of anaerobic and aerobic treatment.

4.4.4.1 CURRENT STATE OF DEVELOPMENT

A consortium of two major Finnish companies (Ra Shipping and Jaakko Poyry) formed JP-Energy OY to market the technology in Scandinavian countries. The North American licencee for the process is Wheelabrator-Frye Inc. of Hampton, N.H.

Both of these companies are engaged in negotiations for feasibility studies for large-scale commercial installations in Sweden and the U.S.A. In addition, the existing intermittent-duty pilot plant will be enlarged to a continuously operated 50,000 tonne/yr demonstration facility. The technology is offered in North America by Wheelabrator-Frye Inc. on the basis of complete design, construction and operating contracts. There are no full-scale installations of the process at this time.

The plants are of modular construction, each process train producing 100,000 tonnes/yr of Peat Derived Fuel (PDF) at 8% moisture, at 80% annual production capacity. The minimum size of plant contemplated would consist of two process trains.

In the estimation of Wheelabrator-Frye, engineering, site acquisition and obtaining of permits would take 9-15 months, the permitting process being the limiting step. About 18 months are required from the completion of engineering to the beginning of startup (J. W. Rohrer, personal communication).

4.4.4.2 FEED CHARACTERISTICS

The process is expressly designed for dewatering wet-mined peat, starting preferably at not less than 10% solids content. Several methods of wet extraction have been proposed in discussions, the choice of the method used would be specific to the site, climate and scale of operations. Unlike dry production methods, wet mining and transportation of peat is still a developing art.

There is no inherent limitation to the humification grade of the peat, but preferred production methods would extract a vertical cut of the bog, homogenizing the well humified bottom layers with the moss found on the top of the deposit.

Experiments at IGT (Mensinger, 1980) showed that the product heating value enhancement over the feedstock calorific value achieved as a result of the process (ranging from 7 to 20%) is dependent on the source of the peat sample and the process conditions, as is the distribution of mass in the recovered solid, liquid and gas phases. The

mass and energy balance of the process is, therefore, somewhat dependent on the material found in a particular peat deposit, and will have to be confirmed in the course of a pre-design study.

Woody materials found in most bogs will be separated by a hydropulper unit (borrowed from pulpmill technology) and used as fuel in the waste-heat boiler. The peat slurry passing the hydropulper is a pumpable fluid at up to 10% solids. If peat enters the plant at a higher solids concentration, it will be diluted by recycled warm process water.

Since the process is characterized by extensive pumping about of peat slurries, erosion in the equipment may pose a problem if the peat contains sand or mineral particles (Prof. B. Myreen, personal comm.). These same particles may also prove erosive to boilers using the product. Therefore, low ash content (< 4%) peat deposits should be chosen for exploitation by this process.

4.4.4.3 PRODUCT CHARACTERISTICS

The process can yield powdered fuel for direct application in some gasifiers, pulverised fuel boilers and the like, or pelletized, nonrewettable particles of a bulk density of 850 kg/m^3 for ease of transport and storage, and application to other gasifiers (e.g. Lurgi) which take pelletized fuel. The product moisture content is 8-10% and the ash and sulfur contents comparable to those of the raw peat.

As noted above, an increase of the specific heating value of the fuel is an expected benefit. The extent of this is variable and specific to the starting material. Myreen (1979) quotes an increase from 20.9 MJ/kg to 25.3 MJ/kg (9060 to 10950 Btu/lb), for the peat used in his experiments.

Wheelabrator-Frye is evaluating a potentially important market for the product: the low moisture and sulfur content allows retrofits of both oil-burning utility and industrial facilities for powdered peat derived fuel (PDF) firing, without the addition of costly flue-gas desulfurization units. Coal-capable boilers now burning oil are also candidates for such modification.

Interest has also been expressed in the use of PDF as an auxiliary fuel for flame stabilization of installations now burning variable moisture content fuels such as green wood-waste and air-dried chips.

In residential, commercial and institutional space heating applications, the uniform size, lack of dust and fines of PDF make it more compatible with automatic storage and handling equipment than coal, woodchips or peat sods would be.

4.4.4.4 PROCESS DESCRIPTION

Raw peat containing up to 90 percent moisture by weight is extracted from the bog by appropriate methods and transported to the plant by belt conveyor or truck. At the plant, the peat is slurried with warm process water, and impurities (sand, gravel, roots) are separated. The slurry is heated to reaction temperature in four stages: first, by hot process water from the dewatering presses; second by backpressure steam from the power recovery turbine exhaust; third, by direct heat exchange with hot wet-carbonized slurry in a multiple-effect condenser-evaporator tower; fourth, by direct injection of high-pressure steam into the reactor.

In the first two stages, the slurry is heated in patented (Myreen, 1980a) rotating tube-bundle heat exchangers. In the third stage, the direct heat exchange is accomplished in a specially designed tower comprised of 10 identical stages of a multiple-effect condenser-evaporator (Nyreen, 1980b). The wet carbonization reactor operates at a temperature of 200°C and 2.5 MPa (392°F, 365 psia), and a residence time of 30 minutes.

The wet-carbonized peat slurry is dewatered to 50 percent moisture in semi-continuous and fully automatic pressure filters. The filter cake is pulverized and further dried to 8-10% moisture in a flash dryer. The dried peat is then pelletized or briquetted.

Chemical energy in the waste water is partially recovered as methane by thermophilic anaerobic digestion with sludge recirculation. The effluent from the digester is further treated in an aerated lagoon to pulpmill effluent discharge standards. Successful operation of this step is claimed to add 6% to the overall energy recovery of the process, based on feed heating value.

4.4.4.5 MASS AND ENERGY BALANCES

An energy balance of the wet carbonization plant (Plate 4-7) shows that 78% of the energy of the peat fed to the plant is recovered in the product. If the feed material contains 20.9 MJ/kg (9060 Btu/lb) and the product has 25.3 MJ/kg (10950 Btu/lb) based on dry matter, at 78% energy recovery, 64.6% of the solids are recovered.

Projected utility requirements based on 1 GJ (40 kg) of product are: 38 litres (10 U.S. gal) of boiler feed water, 0.4 kg (0.9 lbs) of lime, 3.9 kWh of electrical energy.

4.4.4.6 COST ESTIMATES

Capital and operating costs given by Rohrer (1980) were updated to mid-1981, plant capacity was scaled down from 540,000 to 200,000 tonnes/yr, and modified to reflect local conditions: 20 yr depreciation and 20% cost of capital were used to calculate capital charges. The capital and operating cost estimate was based on an exponential scaling factor of 0.7. Capital and operating costs were estimated for Finnish conditions. Wheelabrator-Frye Inc. accepts these estimates as sufficiently accurate for North America at the present level of estimating detail.

Capital costs quoted include all installations within battery limits, waste treatment plant, civil works, construction management and working capital (5.5%).

Cost of a 540,000 tonne/yr plant in early 1979: U.S. $45,750,000. Updated to 1981 by 15% annual escalation, converted to Canadian dollars (C$1 = U.S.$0.83) and scaled down to 200,000 tonnes/yr: $36,370,000.

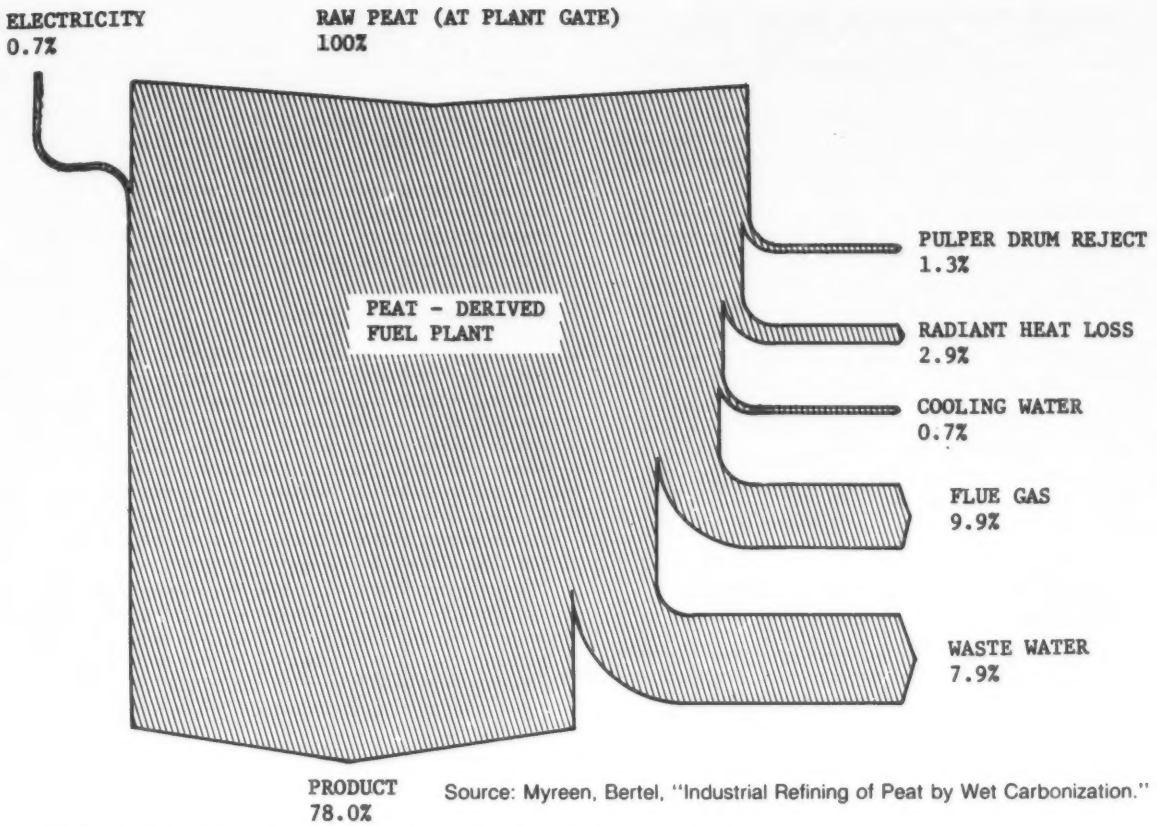
Operating costs for 540,000 tonnes/yr production were given by Rohrer (1980) as U.S.$15,800,000/yr (1979). This was broken down as:

	Oper. costs, % of total
Capital (20 yrs, 13.1%)	39.4
Operating	21.5
Excavation and transport	32.6
Bog preparation	5.7
Bog owner's royalty	0.8
	100.0

Of these, operating costs were extracted, adjusted for inflation, scaled to 200,000 tonnes/yr and converted to Canadian dollars: $2,700,000 per annum.

The cost of wet-mined peat is only approximately known at this time, since there are no wet-mining operating data available on the scale called for in this application. The cost of extracting peat from the bog at 80% moisture content is estimated to be $3.80 per wet tonne. Feedstock accounts for 32.1% of total production cost (Table 4-6). The sensitivity of product cost is $7.10 per tonne, per dollar change in wet peat cost (32.6 cents/10^6 Btu).

Capital charges were recalculated on the basis of smaller scale, 20 years' straight line depreciation and 20% cost of capital $7,470,000 per annum.



Source: Myreen, Bertel, "Industrial Refining of Peat by Wet Carbonization."

PLATE 4-7. THE ENERGY BALANCE OF THE WET CARBONIZATION PLANT.

TABLE 4-6. JP-ENERGY OY WET CARBONIZATION PROCESS.

Cost Estimate Based on data provided by JP-Energy OY and Wheelabrator-Frye Inc.	
Capital investment, June, 1981 200,000 tonnes/yr peat derived fuel at 8% moisture Cost includes all installations within battery limits, waste water treatment plant, civil works, construction management and engineering, working capital, startup.	$36,370,000
Operating Cost, 7000 h/yr	
Labour, utilities, maintenance	$ 2,700,000
Feed material @ 80% moisture, South or South-Central Ontario 1,420,000 tonnes/yr @ $3.80/tonne (estimated)	$ 5,396,000
Transportation of feed, 15 km, $45/h haulage cost, $1.01/tonne	$ 1,434,200
Total Direct Production Cost:	$ 9,530,200
Per tonne of product:	$47.65
Per MBtu (@ 9900/lb)	$ 2.19
Per MJ (@ 2.29 MJ/kg)	$ 2.09
Capital charges: 20 yr, 20%	
Total investment x 0.2 p.a.	$ 7,470,000
Per tonne of product:	$37.35
Per MBtu:	$ 1.71
Per MJ:	$ 1.63
Total Product Cost:	$85.00/tonne $3.90/MBtu $3.71/MJ

4.4.4.7 ENVIRONMENTAL CONSIDERATIONS

Wet carbonization and subsequent dewatering of peat leads to massive amounts (3428 m^3/day, 0.76 MIGD) of strong waste water which cannot be directly discharged into the bog, on account of the chemical transformations that have taken place. The concentration and treatability of this waste is not known from the literature. JP-Energy has commissioned treatability studies and laboratory-scale experiments (by Sorigona AB) suggest that the waste poses no difficulty when treated in a thermophilic, solids-recycle anaerobic digester. The digester effluent is treatable in a conventional aerated lagoon to permissible discharge standards. Furthermore, the digester produces a significant amount of biogas which is burned in the waste-fuel boiler. Biological sludge is also recovered, dewatered and incinerated (6% of energy fed to the plant). The proposed waste treatment system appears to be a modification of the Anamet™ process, developed by Sorigona AB, Sweden. A few such installations are known to operate in the Swedish food industry. The stack-gases are scrubbed before discharge.

4.4.4.8 ASSESSMENT

As there are no full-scale PDF plants operating anywhere, the following areas of technical risk are perceived to exist at this time:

The feasibility studies now proceeding in Finland and in the United States are based on the results of pilot plant studies, without the entire process train having been demonstrated in continuous service.

The reliability of the waste water treatment system needs to be demonstrated, especially its anaerobic digestion section which, in the proposed configuration, represents the leading edge of that technology.

Its success has a bearing on not only the environmental impact of plant operations, but the generated methane gas and sludge form a significant portion of the overall energy economy of the plant (6% of total feed energy).

The mechanical reliability of the novel rotating heat exchangers needs evaluation in the expanded demonstration facility, now being designed.

No doubt, if problems should arise in the above areas, they will be solved if substantial and lucrative markets are generated for the product. After all, the process represents a new departure in peat processing, allowing the large-scale production of quality peat fuel in adverse climatic situations. A lot of interest by potential industrial users has been reported from Sweden, Finland and the United States, and the feasibility of site-specific applications is being investigated. These studies are expected also to result in a consolidation of what is known about the economics of wet-mining, to confirm the economic potential of the process.

4.4.5 THE KOPPELMAN WET PYROLYSIS PROCESS

This process is applicable for the dewatering and upgrading of a variety of high-moisture, low-heating value fuels, to produce dry, homogenous solid fuel of high heating value and low sulfur content. Among such substrates as green wood-chips, lignite and waste bark, a variety of peats were also evaluated in laboratory and pilot-scale equipment and proved the process to be applicable in principle.

4.4.5.1 CURRENT STATE OF DEVELOPMENT

The process is not yet commercially available. A feasibility study sponsored by the U.S. Dept. of Energy is nearing completion at this time. It aims at establishing technical and economic feasibility of placing a peat conversion plant in Washington County, Maine. As an alternative to peat, the study will also evaluate the use of waste bark as a source of feed. Stone and Webster Engineering Corporation, Boston, Mass., is co-ordinating the technical evaluation. The study will be completed in August, 1981. Laboratory and pilot-plant data, collected since 1975 by SRI International, form the basis of the preliminary design which evaluates a 50,000 tonne/yr plant.

If the feasibility study yields a positive evaluation, a single reactor demonstration plant will be built, probably in Maine. The demonstration plant will be ready for operation in the Fall of 1982. Its planned capacity will be 2-3 tonnes/hour. Following successful demonstration, a full-size 4-reactor plant will be built. The process is not expected to be commercially available before late 1984.

4.4.5.2 FEED CHARACTERISTICS

As indicated, a variety of low-grade fuels may be accommodated, in principle. The emphasis of the feasibility study is on the processing of wet-harvested, low humification grade (<H4) Sphagnum peat, which can be mechanically dewatered to <75%. The coupling of a wet-carbonization reactor train to the front end of the process has been suggested but it is unlikely to be economical on this small scale and is not considered in the feasibility study.

The usual preference for low-ash peat applies here too, especially since the reactor configuration would be particularly susceptible to erosive wear in the presence of mineral particles.

4.4.5.3 PRODUCT CHARACTERISTICS

K-fuel, as the solid product is known, may be prepared to a variety of specifications, depending on the intensity of treatment in the reactor, which is under the control of the designer. The volatile matter in the product may be anywhere between 5 and 40%; and the heating value is typically between 28.9 - 31.2 MJ/kg (12500 - 13500 Btu/lb). The sulfur content reflects that of the starting material, whereas the ash content will increase, on account of the loss of volatiles in the course of processing. Physically, K-fuel will be produced either in granular or pelleted form.

4.4.5.4 PROCESS DESCRIPTION

The conceptual flowsheet of the process is presented in Plate 4-8. The heart of the process is an externally heated, inclined tube, through which the feedstock is conveyed by a rotating auger. As the temperature of the feed increases, the moisture is vaporized, then mild pyrolysis occurs. The steam percolates downwards through the reactor, countercurrent to the feedstock and condenses on the cooler solids entering the tube, giving up its latent heat through condensation. Water is drained near the inlet through a slotted screen wiped by the rotating screw.

Pyrolysis products also proceed downwards through the reactor. The tarry materials adhere to the solids and are ultimately partially carbonized. The gases produced have sufficient fuel value to meet the thermal requirements of the process. Pyrolysed product is discharged from the top of the reactor and can be pelletized before it is cooled and removed.

Operating conditions in the wet-pyrolysis reactor are up to 400°C temperature and 10.5 MPa pressure (750°F and 1500 psi). The pilot plant reactor at SRI International has a capacity of 35 kg/h feed.

4.4.5.5 MASS AND ENERGY BALANCE

The only mass and energy balance figures on a consistent basis were published by Phillips *et al.* (1981) and referred to a wood feedstock:

Feed	Products	
46 tonnes/h wood at 70% moisture;	Gases	4.77 tonnes/h 32.9 GJ/h
239.4 GJ/h	Waste water	35.4 tonnes/h 3.88% organics 30.45 GJ/h
	K-fuel	5.8 tonnes/h 174.3 GJ/h

A mass recovery of 42% and an energy recovery of 72% is indicated; there are no figures for processing peat, nor are the exact process conditions known.

4.4.5.6 CAPITAL AND OPERATING COSTS

Economic evaluation has not been published; cost figures are being calculated in the course of the feasibility study.

4.4.5.7 ENVIRONMENTAL CONSIDERATIONS

Waste water treatment options are in the course of evaluation in the feasibility study. The alternatives under consideration are anaerobic digestion with methane recovery, (presumably followed by aerobic treatment), and wet air oxidation.

4.4.5.8 ASSESSMENT

In the absence of mass and energy balances, it is impossible to give a meaningful evaluation of capital and operating costs before the results of the feasibility study become known later this year.

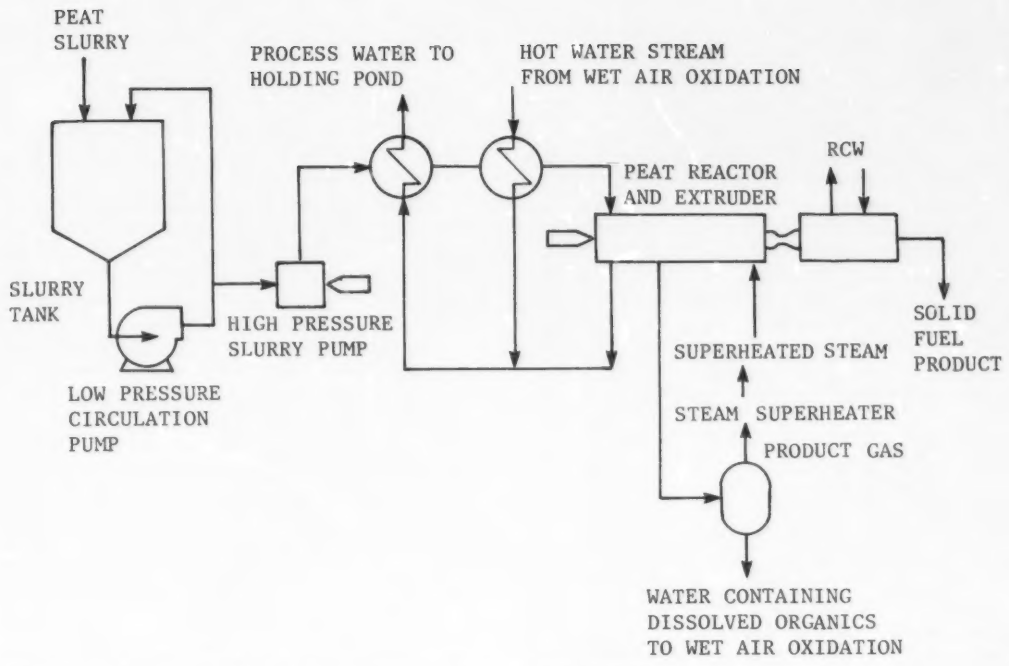


PLATE 4-8. SIMPLIFIED FLOW DIAGRAM OF KOPPLEMAN PROCESS.

4.5 CHEMICAL PROCESSING OF PEAT

4.5.1 GENERAL

The subject area dealing with the chemical processing of peat is defined here as those conversions which result in products other than solid fuels: viz. fuel gases, synthesis gas, methane, hydrocarbon liquids and methanol. The discussion of biologically mediated conversions will be considered in the next chapter.

4.5.2 GASIFICATION PROCESSES

4.5.2.1 GENERAL

Gasification processes convert a solid carbonaceous feed (biomass, peat or coal) to a gaseous fuel that may be burned directly, upgraded to higher quality fuels (e.g. SNG) or used as a feedstock for manufacturing chemicals (e.g. methanol, ammonia, hydrocarbon liquids).

The prime justification for gasifying peat on whatever scale is the possibility of retrofitting existing natural gas or oil-fired boilers to fuel gas generated from peat at a cost which appears to be less (about 66%) than the cost of a new solid-fuel installation (Reed *et al.* quoted in Retrofit '79, 1979). On a substantial scale (80-250 x 10^9 Btu/day), substitute natural gas generation technology is under development, using milled peat for feedstock.

Two other factors will make gasification for existing boilers an attractive option, once these technologies are fully adapted to peat. Gasifiers typically have low particulate emissions because the particulates are removed in the gasifier before passing to the combustion unit. Even if some further cleanup is required, the volume of gas from the gasifier requiring cleanup is typically less than the final flue products from combustion; and the gases are much cooler.

In a gasifier, peat dried to at least 50% moisture enters the reactor, in which it combines with air or oxygen and steam to yield gaseous and liquid products and a solid residue which may be ash or char, depending on the gasifier. The gaseous products may be low, medium or high-Btu gas.

Low-Btu gas (LBG) is produced in air-blown gasifiers. Its heating value is 3.7 to 9.3 MJ/m^3 (100-250 Btu/ft^3), since the combustible gases (CO, H_2, CH_4) are diluted with about 50% nitrogen. The versatility of low-Btu gas is limited and its use is subject to the following considerations:

- substitution of low-Btu gas for natural gas as an industrial boiler fuel usually requires boiler derating and/or extensive retrofit modifications.
- the low heating value of the gas usually requires that it be consumed on or near the production site in a close-coupled process.
- it is not compatible with natural gas in existing distribution systems.
- the high nitrogen content of the gas precludes its use as a synthesis gas.
- the maximum attainable flame temperature is limited to 800-1000°C.

On the other hand, since no oxygen generating facility is needed, the approach may be economical in some circumstances. One such application is discussed in this chapter.

If oxygen is injected into the gasifier, medium-Btu (MBG) gas is produced, with the heating value in the 9.3-20.5 MJ/m^3 (250-550 Btu/ft^3) range. Medium-Btu gas offers some advantages over low-Btu gas:

- boiler derating is usually less severe when substituting MBG for natural gas than when LBG is substituted, and may not even be required in some cases.
- MBG can be transported over moderate distances by pipeline at a reasonable cost.
- MBG can serve as feedstock for chemical syntheses after adjusting the carbon-hydrogen ratio catalytically or by the addition of hydrogen from an external source. In this application, medium-Btu gas is known as "synthesis gas".

The major disadvantage of MBG is that its production requires the use of an oxygen-blown gasifier, and the production of oxygen increases capital and operating costs.

High-Btu gas, consisting of over 90 mole % methane and possessing a calorific value between 35.5-37.3 MJ/m^3 (950-1000 Btu/ft^3) is produced in gasifiers designed for this purpose (PEATGAS, CS/R Hydrogasifier) followed by a catalytic methanation step. This product is similar to natural gas in chemical composition and heating value, and is intended for use as substitute natural gas (SNG) in pipeline systems.

Before discussing peat gasification process development, the chemistry of thermal gasification will be discussed briefly. The chemical reactions that peat is subjected to are the same as those occurring during coal gasification. However, their rate and extent may be quite different. The physical characteristics of peat and peat ash are also different from those of coal. Therefore, the peat gasifiers under development at present attempt to take these factors into consideration. There are close similarities between the chemical behaviour of cellulosic biomass and peat in gasification.

In a generalized example of a gasifier, a particle of peat travelling through the reactor will initially give up its residual moisture to the hot gases surrounding it. As its temperature rises (150-500°C), it will undergo pyrolysis, yielding a mixture of volatile compounds and a solid char, which consists largely of carbon and ash. Pyrolysis cannot be referred to as a single reaction or a set of well-defined chemical reactions. The reactant is complex and reacts with a complex mixture of gaseous materials it encounters, along reaction paths that have only partially been understood. The pyrolysis reaction itself is mainly dependent on the temperature and heating rate. These influence the yield of char and the volatile product mix, which can contain aromatics, aliphatic hydrocarbons, tars, etc. A good review of pyrolysis is given by Rensfelt *et al.* (1978).

Depending on the reactor design, the pyrolysis products may be withdrawn with the effluent gas or passed through a hot bed of char where the more complex molecules are cracked to methane, carbon and a small amount of simple aromatics (benzene, toluene, xylene, phenol), as in Equation 1, Table 4-7.

TABLE 4-7. CHEMICAL REACTIONS DURING GASIFICATION.

Reaction			ΔH_{25}, KJ/mole
(1) Volatile Matter	⇌	CH_4 + C	slightly exothermic
(2) C + 1/2 O_2	⇌	CO	− 111
(3) CO + 1/2 O_2	⇌	CO_2	− 254
(4) H_2 + 1/2 O_2	⇌	H_2O (g)	− 242
(5) C + H_2O (g)	⇌	CO + H_2	+ 131
(6) C + CO_2	⇌	2 CO	+ 172
(7) C + 2 H_2	⇌	CH_4	− 75
	Fe or Ni cat.		
(8) CO + 3 H_2	⇌	CH_4 + H_2O (g)	− 206
(9) CO + H_2O (g)	⇌	H_2 + CO_2	− 41
	Ni cat.		
(10) CO_2 + 4 H_2	⇌	CH_4 + 2H_2O (g)	− 165

From: Leppamaki *et al.* 1979

The solid residue of pyrolysis (char) now enters the gasification zone, where it is contacted with air, oxygen or steam, or a mixture of these, and undergoes oxidation-reduction reactions.

The most important reactions and enthalpy changes (at 25°C) are listed in Table 4-7. Negative enthalpies show that the reaction is exothermic; positive enthalpies signify an endothermic (heat consuming) reaction.

The first reaction in Table 4-7 shows the thermal decomposition of organic molecules to simple ones, such as methane and carbon. This reaction takes place above 800°C. Reactions 2, 3 and 4 are the usual heat-generating reactions in combustion. They also take place in the gasification process if oxygen is present, generating heat to carry out the endothermic water-gas reaction (Eq. 5), in which steam and carbon react. This reaction is important, as it generates hydrogen. The steam injected here provides not only water molecules, but may supply part of the reaction heat. The equilibrium favours the production of carbon monoxide between 800-1000°C.

The CO-shift reaction (Eq. 9) is important when the CO-H_2 ratio needs to be adjusted prior to methane production (Eq. 8) or methanol synthesis. The CO-shift takes place in the gasifier to a certain extent, but the final adjustment of synthesis-gas composition is carried out in an external catalytic shift-converter.

If the hydrogen content of the gas is high, reactions 7, 8 and 10 produce methane (hydrogasification). Methane production is favoured at high reactor pressure. These reactions are highly exothermic and improve the thermal efficiency of the process. The methanation reactions (Eq. 8 and 10) may also be carried out in an external catalytic methane converter if SNG is the desired product.

In thermal gasification processes the product yields and process thermal efficiencies depend on the operating temperatures and pressures, the type of gas-solids contacting and the method of supplying heat needed for the reactions. It is important to note that, even though the cost of the gasification section of an SNG-from-peat plant (e.g. PEATGAS) is only about 15% of the total plant investment, it is the heart of the plant and it determines the efficiency and product distribution of the total plant. In most gasification processes, the heat required is generated in situ by feeding air or oxygen for partial combustion of the peat. Indirect heat is supplied in the form of superheated steam in some processes.

Gasification processes could consist of one or more reaction stages. Each of the stages could incorporate one of the several types of solids flow: moving packed bed (e.g. Lurgi), entrained flow (e.g. Koppers-Totzek) or fluidized bed (e.g. Winkler). The gas-solids contacting in the moving packed bed reactors could be either in the countercurrent mode or in a co-current mode (gas and solids both moving down). Gas-solids flow in the entrained-flow reactor is always in the co-current mode, while the fluidized bed reactor most closely corresponds to a completely stirred system.

Peat in its gross chemical composition, volatiles content and heating value falls between cellulosic biomass and coal (Table 2-13). Historically, most of the processing routes investigated first applied coal gasification techniques to peat feedstock. In early experiments, peat was fed to unmodified gasifiers designed to process coal (Lurgi, Koppers-Totzek, Winkler). On account of the difficulties encountered in feeding and keeping peat particles in the gasifiers, these attempts were unsuccessful on a technical scale. The low prices of competing fuels did not encourage further development until the mid-seventies. Leppamaki *et al.* (1979) published a thorough review of early peat gasification work.

In spite of the materials-handling problems, peat does offer advantages over coal as a raw material for gasification:

- it contains about 60% more volatile material than lignite, and volatiles are much easier to convert to gases and liquids than is fixed carbon,
- the char produced is much more reactive in the gasifier than coal-char, resulting in higher overall carbon conversions than lignite under similar conditions, and
- peat has lower sulfur content, saving gas cleanup costs.

However, the lower ash softening temperature of the peat (~ 1100°C) requires more careful control of the reactor in non-slagging gasifiers than is necessary in the case of coal.

There are close similarities between the chemical behaviour of cellulosic biomass and peat during gasification. For this reason, gasification process development is often

carried out concurrently with peat and biomass (e.g. wood chips) feedstock (e.g. at Studsvik and RIT, Sweden).

Peat gasifier designs may be classified into relatively simple, first generation efforts, which produce low to medium-Btu gases in equipment which are modified versions of coal gasification reactors (e.g. Koppers-Totzek, Winkler). The second generation of peat gasifiers form part of integrated chemical plants, capable of producing a range of products: methane, liquid hydrocarbons and synthesis gas and recover by-product ammonia and sulfur. The IGT PEATGAS and the Cities Service/Rockwell Advanced Hydrogasification processes are examples of these. The Studsvik-RIT MINO process design for a synthesis-gas pilot development unit is the result of a thorough thermodynamic analysis of the entire peat to methanol process train.

With the exception of the following two processes, all the above are in the pilot or demonstration unit stage of development. A small (~ 1 MW) sod gasifier coupled with a diesel-generator set will go on the market in late 1982 (VTT, Finland), and a 600 tonne/day peat-to-methanol plant, based on the Koppers-Totzek gasifier, is in the design phase, scheduled for startup in 1984 (Peat Methanol Associates, Washington, D.C.) A number of gasification processes will be reviewed below.

4.5.2.2 PRODUCTION OF FUEL-GAS WITH GASIFICATION OF PEAT IN A FIXED BED

Both co-current and countercurrent gasification of peat in a fixed bed have been experimentally studied at the Fuel and Lubricant Research Laboratory of the Technical Research Centre of Finland (VTT) (Salo *et al.* 1980).

Both gasifiers use air injection, and produce low-Btu gas. The two gasification methods differ from each other primarily in the respect that, in the co-current method, pyrolysis products are carried through a glowing peat layer. As a consequence, they are cracked and the product does not contain tarry materials. The gas leaving the reactor is hot (~ 800°C). The maximum practical size is 1 MW thermal output.

In the countercurrent gasification method, the pyrolysis products are carried away in the gas developed in the gasification zone. The gas leaving the reactor contains tar and steam, and it is relatively cool. Gasifiers up to 25 MW size are practical.

The countercurrent peat sod gasifier is still in the pilot development stage. It will be useful in applications where the gas can be used without cleaning, for example, in industrial boilers where the temperature requirements are not high (800-1000°C). The efficiency of the system will be good in these applications, as it can be as high as 95% in the actual gasification. Heating value of the gas is ~ 6 MJ/m^3 (150 Btu/ft^3).

The co-current gasifier produces gas which may be directly injected into a modified diesel or otto engine, after cooling to 30-50°C. For this reason, it appears to be suitable for small electrical generation stations, fuelled by locally produced sod-peat. Considering its potential for use in remote communities, and near-term commercial availability, this is the configuration chosen for detailed discussion in this section.

CURRENT STATE OF DEVELOPMENT. Experimental development of the co-current gasifier was started at VTT in 1976 with a small unit of about 200 kW thermal. A demonstration unit (about 1 MW) is under construction. The gasifier will be tested this year. It will later be coupled to a diesel-electric generator set. Commercialization of gasifier plus diesel generator equipment will be handled by Kankaanpaan Teras OY, of Kankaanpaa, Finland. It is estimated that the first commercial unit may be available in late 1982.

Operating characteristics of the gasifier limit its maximum size to about 1 MW thermal. The commercial unit will, therefore, be designed for 400 kW electrical and 490 kW thermal energy output.

FEED CHARACTERISTICS. The calorific value of the gas produced is influenced by the moisture content of the peat used. For 55% moisture content, it was 3.1 MJ/m^3 (83 Btu/ft^3), for 10% moisture content 4.2 MJ/m^3 (113 Btu/ft^3) were generated.

Sod-peat is to be used in the gasifier. The fines content of the feed should not exceed 50%, preferably 30%. Milled peat cannot be used. Tests show that peat briquettes (moisture content 14%) disintegrated in the combustion zone and clogged the gasifier. Peat pellets (25 x 12 mm) may be used.

PRODUCT DESCRIPTION. The heating value and composition of the gas produced varies with the moisture content of the feed, as shown in Table 4-8.

PROCESS DESCRIPTION. Sod-peat is fed into the top of the gasifier. Air is injected into the combustion zone. Gas is withdrawn after it travels downwards through the combustion zone, which eliminates the carry-over of tars and condensable products other than water vapour. The combustion zone temperature must not reach the melting point of the ash (~ 1100°C). The low melting point of peat ash limits the maximum capacity of the gasifier to about 1 MW, since uneven distribution of fuel and gases in larger firing chambers may give rise to localised hot spots. Ash will melt in these high-temperature regions and will further aggravate the channelling problem.

Before injection into a diesel engine, the gases must be cooled to 30-50°C, allowing the condensation of moisture and the recovery of heat, which increases the overall thermal efficiency of the unit. The engine is coupled to an electric generator.

MATERIAL AND ENERGY BALANCE. Using sod-peat of calorific value of 14.7 MJ/kg (7000 Btu/lb) at 35% moisture, the chemical efficiency of the gasifier is said to be 58.5%; with heat recovery from cooling the gases from 800 to 50°C, the total efficiency is 86%.

The motor-generator efficiency anticipated is 30%. It is expected that 6 to 10% of the energy to the diesel engine will still have to be supplied in the form of fuel oil.

For 400 kW electrical energy output, 1200 kW of chemical energy is required, 10% of this supplied in the form of fuel oil, leaving 1080 kW of chemical energy to be supplied in the form of peat, at the chemical efficiency applicable to the conditions viz 58.5%: 1847 kW of peat fuel and 120 kW of fuel oil are required. An additional 490 kW of thermal energy is said to be recoverable by heat exchange from the gases.

TABLE 4-8. COMPOSITION OF GASES PRODUCED IN CO-CURRENT GASIFICATION OF PELLETS AND SODS.

Fuel	Moisture Content %	Gas Composition H_2 %	CO %	CO_2 %	N_2 %	Calorific Value of Gas MJ/m^3	Chemical Efficiency %	Total Efficiency Heat Utilized 800°→150°C %	800°→50°C %
Pellets	17	13.5	19.8	15.2	50.7	4.1	55	74	80
Pellets	30	13.3	17.5	15.6	52.7	3.8	55	77	85
Sods	35	14.5	19.0	12.5	54.0	3.9	58.5	78	86

Therefore, to produce 400 kW electrical and 490 kW thermal energy, at 6000 hours/yr peak loading time, 2.46 x 10^3 tonnes/yr of sod-peat and 62 tonnes/yr of fuel oil are required. The overall thermal efficiency of the system is 45.2%.

CAPITAL AND OPERATING COSTS. The capital cost of the gasifier-generator unit is estimated by VTT to be about $500/kW of total energy output. Since the equipment is not yet available, this estimate is still uncertain. Furthermore, the minimum economical sod-peat production scale is about 5000 tonnes/yr. Therefore, two gasifiers must be operated in parallel to achieve the sod-peat feed cost of $49/tonne (Section 5.9.2). The cost estimates are given in Table 4-9.

TABLE 4-9. SMALL-SCALE SOD PEAT GASIFIER.

Cost Estimate (1981)

Based on data supplied by VTT, Finland.

It is assumed that two units are operated in parallel, for 6000 peak operating hours/yr. Other assumptions are detailed in Mass and Energy Balance.

Capital Investment, one unit	
400 kW electrical energy	
490 kW thermal energy at 150°C	
$500 per kilowatt, thermal and electrical output	$445,000
Working capital, 2% TIC	9,000
Total Capital Investment:	$454,000
Operating Cost, 6000 h/yr, for one unit	
Fuel: sod peat at 14.7 MJ/kg, $49/tonne, 2.46 x 10^3 tonnes/yr	$119,500
oil at $10.00/GJ, 62 tonnes/yr	$ 26,473
Maintenance and lubricants, $3.14/MWh, thermal and electrical	$ 16,770
Labour: 4 men, 1 per shift, for 2 units 2 man/years, at $20,000/yr	$ 40,000
Total Direct Production Cost:	$202,743
Capital Charges 10 yr, 20% CRF, one unit Total investment	$108,300
Cost of Electricity Produced	
Credit for heat sold at $7.62/GJ ($8.00/MBtu), 490 kW for 6000 h	($ 80,297)
Net cost of electricity, 400 kW for 6000 h	$0.096/kWh
If no credit is taken for heat generated	$0.13/kWh

ENVIRONMENTAL CONSIDERATIONS. The only emissions from the total plant are diesel exhaust gases, ash from the gasifiers (246 tonnes/yr at 5% ash content in feed) and a small amount of condensate water (4.8 m^3/day, 1000 IGD), which may be contaminated by combustion products.

ASSESSMENT. The economic evaluation looks attractive for application to remote, small communities where the electrical supply is through diesel-powered generator sets, even if the waste heat cannot be sold. The economic potential of this equipment will be evaluated in greater detail in Part 5.

The uncertainties that exist relate to the experimental nature of the development done so far, and the data upon which the cost estimate was based. However, development continues, and a manufacturer has been contracted to commercialize the process.

4.5.2.3 MEDIUM-BTU OR SYNTHESIS GAS PRODUCTION

GENERAL. By heating peat with oxygen and steam, it is possible to produce medium heating-value gas, or synthesis gas, which offers several opportunities for further processing. Synthesis gas is the first step in the production of chemicals such as methanol, ammonia and Fischer-Tropsch products. The major gasification techniques are fixed-bed, fluidized bed and entrained-flow gasification. The most advanced commercial coal and brown coal gasification plants make use of the latter two techniques. Among the best known processes are those of Lurgi, Koppers-Totzek and Winkler. These will be discussed below.

A general trend in gasification methods is towards pressurized systems: the exothermic methane-generating reactions occur at higher pressures which increase the overall thermal efficiency. For some applications, however, (e.g. methanol production) high methane content in the gas is a disadvantage. The size of a pressurized generator of a given capacity can be reduced in comparison with atmospheric pressure operation and heat recovery is more economical from compressed gases than from those at lower pressures. All three gasification processes mentioned have been originally designed for brown coal or bituminous coal. Experience with peat in the production of synthesis gas is rather scarce. Comprehensive reviews were published by Leppamaki *et al.* (1979), Solantauste and Aspland (1980) and Punwani (1980).

Application of coal gasification technology to peat feedstock typically requires new designs for the storage, preparation and feeding system, and a modification of the gasifier to accommodate the low density and low ash melting temperature of the peat.

If the gas produced is burned for fuel, it is appropriate to call it medium heating value gas. In this application, the presence of tars and volatile hydrocarbons is not a disadvantage. On the other hand, if the gas is utilized for feedstock in methanol synthesis (as an example), a low (<5%) content of inert gases (N_2, CO_2, CH_4) is desirable; gas cleaning steps will also be necessary if the reactor produces gas with high tar content.

The chemistry of synthesis gas production has been described in Section 4.5.2.1.

A newly developed synthesis-gas reactor system, the MINO process is under development by Studsvik Energieteknik AB and the Royal Institute of Technology of Sweden. These processes and experimental results using peat with conventional coal gasifiers will be detailed later. Peat Methanol Associates of Washington, D.C., are designing a 614 tonne/day peat to methanol facility, based on a Koppers-Totzek gasifier. This project will be described in Section 4.5.3.2.

LURGI. Gasification is accomplished in a slowly descending fixed-bed in a vertical reactor. The largest reactor in operation is about 3.7 m in diameter. The reaction is carried out under pressures of 1.0 to 3.0 MPa and temperatures of 620 to 760°C.

The feed peat (or coal) is introduced at the top through a lockhopper system and spread evenly across the reactor by a rotating distributor. Superheated steam and oxygen are fed at the bottom of the reactor.

Raw gas leaves the reactor at the top. As a result, tar, ash and dust are mixed with the gas, and extensive cleanup is necessary before the synthesis gas can be further processed. The temperature of the outlet gases is between 370-600°C. The thermal efficiency of the Lurgi gasifier is about 70% on coal feedstock. The composition of the gas may be varied through the steam/oxygen ratio; air may be used instead of oxygen if low-Btu gas product is desired. Results of gasification tests with Irish peat in a Lurgi pilot plant are given in Table 4-10.

The typically high methane and tar content of the gas makes the Lurgi gasifier of limited use in synthesis gas production, but close-coupled industrial boiler applications may be possible.

Feedstock Requirements:

Particle Size	0.3-9.8 mm
Moisture Content	< 20 to 22 weight percent
Ash Fusion Temperature	> 1100°C

KOPPERS-TOTZEK. The Koppers-Totzek reactor is an entrained-flow gasifier consisting of a refractory-lined horizontal cylindrical vessel with two or four nozzles facing each

TABLE 4-10. RESULTS OF GASIFICATION TESTS CONDUCTED IN A LURGI GASIFIER WITH PEAT.

Test No.	2	10
Operating Conditions		
Peat Feed Rate, kg/h	1057	943
Pressure, MPa	1.97	1.47
Operating Results		
Liquid Products, kg/h		
Tar	58.5	43.0
Oil	13.4	9.34
Light Hydrocarbon Liquids	7.12	5.76
Gas Yield, m^3/kg	1.34	1.54
Gas Composition (Dry Basis), mol %		
CO	17.0	17.4
CO_2	33.8	33.0
H_2	34.2	37.1
CH_4	13.6	11.2
C_nH_m	0.6	0.6
H_2S	0.1	0.1
N_2	0.7	0.6
Total	100.0	100.0

Peat was gasified by a mixture of oxygen and steam under pressure
From: Leppamaki *et al.* (1979)

other coaxially. Superheated steam, oxygen and finely ground coal (or peat) are fed into the reactor through the nozzles. A schematic diagram of the gasifier is shown in Plate 4-9. The reactor operates at slightly above atmospheric pressure, near 1100°C and the residence time is a few seconds.

The outlet temperature of the gas can be as high as 1600°C. As a result of the low pressure and high temperature, the outlet gas does not contain hydrocarbons, tar or phenols in any significant concentration. The ash is removed partly through the bottom of the reaction chamber, partly from the product gases in a cyclone and wet scrubber.

The K-T gasifier is flexible in operation: full production capacity can be reached in 30-60 minutes from startup. The thermal efficiency is about 75% on coal feed.

The results of some gasification tests carried out using a Koppers-Totzek gasifier are shown in Table 4-11. 85-90% carbon conversions are achieved.

TABLE 4-11. RESULTS OF TESTS IN A KOPPERS-TOTZEK GASIFIER.

Quantity of Peat Dust Fed: ~ 2500 kg/h	Test 1	Test 2
Outlet Temperature of Gas, °C	1200	1090
Consumption/m^3 CO + H_2		
Peat Dust (dry), kg	0.949	0.931
Oxygen (98.5%), m^3	0.453	0.385
Steam, kg	0.141	0.135
Gas Analysis (dry gas), %		
CO_2	15.8	14.9
O_2	0.2	0.2
CO	45.9	45.8
H_2	32.5	33.4
N_2 + Ar	4.5	4.2
CH_4	1.1	1.5

From: Leppamaki *et al.* (1979)

In Finland, peat has been gasified with Koppers-Totzek gasifiers by Typpi OY on an industrial scale in the 1960s for ammonia synthesis. The most serious drawbacks found were high oxygen consumption, and the extensive requirements for pretreatment, such as drying and milling (8% H_2O, < 0.7 mm). Because of the very low density of peat powder, there is a problem of plugging when feeding the K-T gasifier. The milling operation was also plagued with small dust explosions. Nevertheless, peat can be gasified in this equipment, provided special attention is paid to its handling and feeding to the gasifier.

A consortium of U.S. companies is planning a 614 tonne/day methanol plant to operate on synthesis gas prepared from milled peat by Koppers-Totzek technology. This project will be described later in Section 4.5.3.2.

Shell and Krupp-Koppers of Essen, West Germany, are developing a high-pressure version of the process.

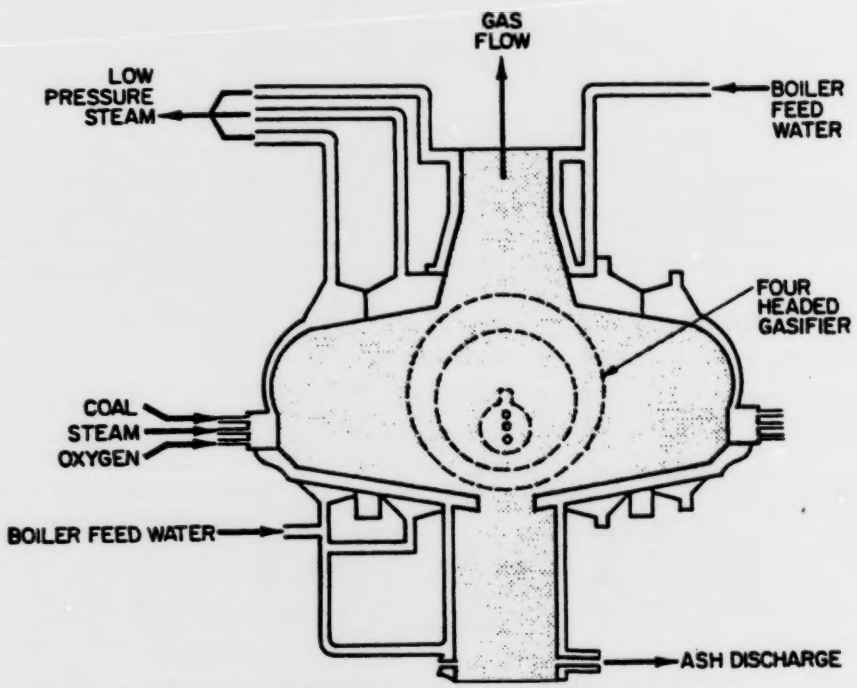


PLATE 4-9. SCHEMATIC DIAGRAM OF A KOPPERS-TOTZEK GASIFIER.

WINKLER. The Winkler gasification process has been used commercially with coal for many years to produce low- and medium-Btu gas.

The gasifier is a refractory-lined cylindrical tower equipped with a funnel-shaped bottom. Coal is screw-fed near the bottom of the gasifier and the larger particles are gasified in a fluidized bed. The smaller particles are carried over with the gas and gasified in the upper zone of the reactor with excess steam and oxygen.

The temperature of the gasification zone ranges from 815° to 1100°C; the pressure is slightly above atmospheric. A thermal efficiency of 75% has been reached with this gasifier.

The high temperatures reached in the upper part of the reactor allow complete cracking of tar and higher hydrocarbons. On the negative side, it is difficult to gasify peat with fluidized bed methods, because of the excessive carryover of fines in the exhaust gas.

A high-pressure (1.1 MPa) version of the Winkler gasifier is marketed by Uhde. Studsvik Energieteknik is planning pilot experiments with a pressurized version of this gasifier. With pressurized operation, some heat recovery is possible, and the treated gas volumes are smaller than at atmospheric pressure.

MINO PROCESS. During 1979-80, an extensive feasibility study was undertaken in Sweden by Studsvik Energieteknik AB and the Royal Institute of Technology, to assess different conceptual processes for the production of synthesis gas from peat and wood biomass, in order to arrive at an optimum design for a 500 kg/hr pilot development unit. This study (Engström *et al.* 1979) was centred around the thermal efficiency for different process trains. It showed that an optimized peat to methanol process will have a thermal efficiency of approximately 50% (HHV). A typical breakdown of production costs shows that raw materials account for 40% and gasification cost (at 20% return on investment) 6% of product cost.

Based on these figures, it is easily calculated that a doubling of the gasification cost can be tolerated if the efficiency is thereby raised from 50% to 59%. Therefore, rather sophisticated solutions can be justified which increase the thermal efficiency by even a small portion.

Of the several alternative process concepts examined, an autothermal, oxygen based, two-stage process evolved, which forms the basis of the proposed PDU. The expected efficiency of the process from peat to biomass to methanol is 54% (HHV), based on peat or biomass fuel at 50% moisture (Engström *et al.* 1981).

The gasifier is a 0.4 m ID fluid bed with a refractory lined pressure vessel designed for operation at 3 MPa and 900°C. The gasifier will be provided with means for feeding fuel from above through a lock-hopper and from the side into the bed by using a screw feeder, and another screw for removing ash from the bed bottom. Steam and oxygen will enter the gasifier through nozzles at the bottom and steam can be injected above the bed for temperature control. The flow scheme is shown in Plate 4-10.

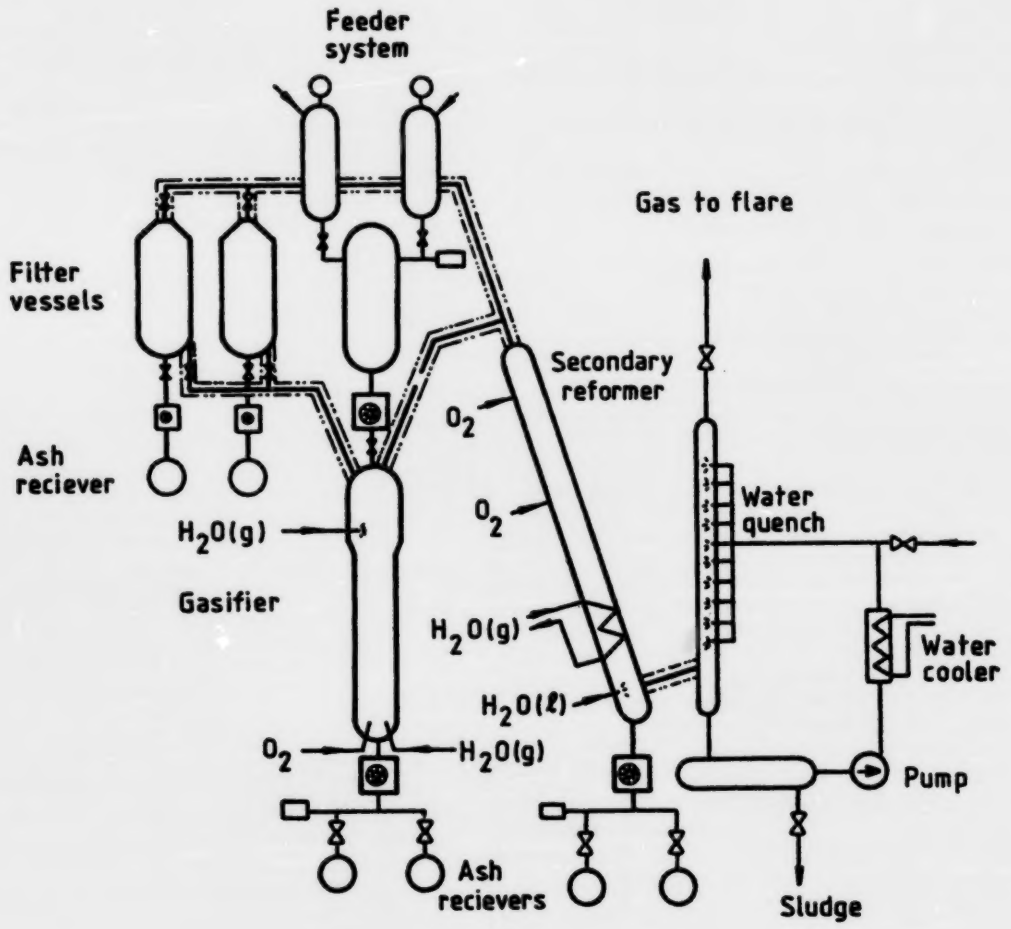


PLATE 4-10. MINO PDU FLOW SCHEME

The unit will use two alternately operating filter vessels containing sintered refractory filter elements. From the filter vessel in operation the gas will go to the secondary gasifier, a refractory lined pressure vessel designed for 3 MPa and 1300°C, containing the catalyst bed, and into which oxygen is injected. At the bottom of the secondary gasifier, the gas will be cooled in two stages before entering the water quench where steam and residual tar is condensed and after which the gas will be flared.

The unit incorporates fuel storing, drying and milling facilities as well as liquid gas tanks and vaporizers for the gases used, compressors and pumps.

The prime goal for the unit is to develop the process as described above, but a certain flexibility will be included to facilitate testing of different feeding systems and non-catalytic (thermal) secondary conversion of tar and methane.

The unit will have a capacity of 500 kg/h (dry basis) and the total erected cost will be approximately 5 million U.S. dollars. The unit is planned to start operation in late 1982. Plans for commercial plant designs are not yet firm.

To facilitate design and specification of experimental parameters, the bench-scale unit at the Royal Institute of Technology will be operated as a steam/oxygen fluidized bed, and a secondary gasifier for this bench scale unit is planned to start up in early 1982. Thermal conversion of tar and methane will be further studied at the Lund University of Technology with a small scale atmospheric pressure reactor. These units will be powerful tools to make important contributions to the development of synthesis gas production from wood and peat.

4.5.2.4 PEATGAS™

PEATGAS process development was started at the Institute of Gas Technology (IGT) under the sponsorship of the Minnesota Gas Company (Minnegasco). The U.S. Department of Energy has shared the cost of development since 1976. The co-funding group now includes the Gas Research Institute (GRI) and the Northern Natural Gas Company.

The original intention of the development program was to produce substitute natural gas (SNG) from peat, but the reaction kinetics were investigated in sufficient detail to allow the design of processes which yield medium heating value gas for use as an industrial fuel, or synthesis gas for the production of methanol.

CURRENT STATE OF DEVELOPMENT. All the experimental work to date has been concentrated on obtaining data on the characteristics of peat in the two stages of the PEATGAS process. Tests have been conducted on the individual stages of hydrogasification and char gasification in laboratory and PDU-scale equipment. The objective of the PDU-scale tests was to check the accuracy of the kinetic model and to determine the effects of scaleup from bench scale tests. The two stages of the PEATGAS reactor will be integrated in the pilot plant, which was scheduled for startup in the spring of 1981.

The U.S. Department of Energy is funding a U.S. $4 million, 19 month feasibility study (initiated in October, 1980). The Dravo Corporation (Pittsburgh, Pa) is under contract to IGT to carry out a detailed feasibility study for an 84 TJ/day (80 x 10^9 Btu/day) SNG plant.

If the feasibility study and pilot development program show favourable results, Minnegasco is interested in the construction and operation of an 84 TJ/day scale plant for the production of SNG from peat.

FEED CHARACTERISTICS. The PEATGAS process is based on milled peat arriving at the plant containing 50% moisture. Feed peat is ground to 100% –8 U.S. sieve size (< 2 mm) using a hammermill. The peat is pre-dried from 50% to 35% water content in a peat-fuelled dryer.

Laboratory studies have shown that peat samples originating in different locations (Minnesota, North Carolina and Maine) and being of different degrees of humification have different gasification characteristics and the plant design will have to take this into consideration. The differences are reflected in the amount and distribution of by-products, the size of the methanation reactor, and ultimately in the cost of gas produced. The example discussed in this section is based on Minnesota peat.

PROCESS DESCRIPTION (After Punwani and Biljetina, 1980). The PEATGAS process is a two-stage gasification system for converting peat to synthetic fuels: methane (SNG), medium-Btu fuel gas, synthesis gas and by-product liquid fuels. Peat, containing 30 to 50% moisture is milled to particles smaller than 10 mesh (2 mm) and is fed to the top of the reactor using lockhoppers. The reactor is schematically illustrated in Plate 4-11.

Prior to entering the gasification zone, the peat passes through a fluidized-bed dryer which is integral with the reactor vessel and is located on top of it. Here the incoming peat is preheated and dried by the gases leaving the hydrogasifier. The dried peat then flows down a standpipe into the hydrogasification stage, where flash pyrolysis takes place in the presence of hot, hydrogen-rich synthesis gas rising through a fluidized bed of reacting peat solids.

A fraction of the total peat feed can also be injected into the hydrogasifier without going through the dryer. This feature allows the flexibility of changing the hydrogasifier temperature without changing the operating conditions in the char gasifier. The gas from the hydrogasifier flows up to the drying stage, and the pyrolysed char flows down by gravity to the char gasifier stage where it is reacted with steam and oxygen in a fluidized bed to make synthesis gas. Essentially complete conversion of the feed carbon is achieved in the two stages. The hot ash is discharged from the system and quenched by recirculating water. The resultant ash-water slurry is filtered and the filtrate is recycled.

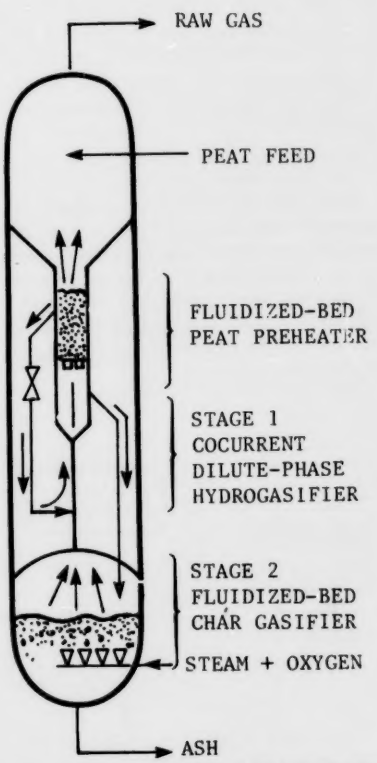


PLATE 4-11. SCHEMATIC DIAGRAM OF THE PEATGAS REACTOR.

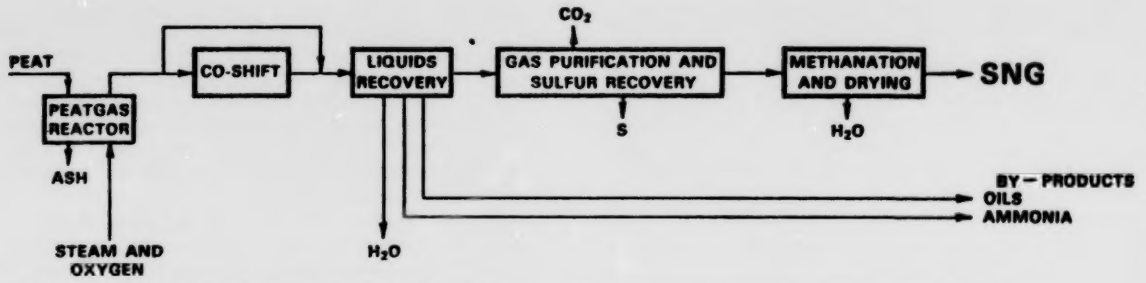


PLATE 4-12. CONCEPTUAL FLOW SHEET FOR PRODUCTION OF SNG FROM PEAT BY THE PEATGAS PROCESS.

The product distribution from the PEATGAS reactor can be easily controlled by regulating the temperature in the hydrogasification stage. The effects of temperature and the control alternatives have been described by Punwani and Biljetina (1980). In effect, the PEATGAS Process can be designed to produce one of three primary products: methane (SNG), medium-Btu fuel gas or synthesis gas for further processing into methanol or Fischer-Tropsch products (synthetic gasoline).

High-Btu Gas (methane, SNG). A schematic flow diagram for SNG production is shown in Plate 4-12. For maximising methane production, the hydrogasifier is operated at 3.55 MPa (514.7 psi) and above 704°C (1300°F) with no wet peat being fed to the hydrogasifier. The steam-to-carbon mole ratio in the char gasifier is about 0.4, and the char gasifier is operated at 930°C (1700°F). At these operating conditions, as much as 84% of the methane is made directly in the gasifier. The remaining 16% is made by catalytic methanation. The liquids produced under these conditions correspond to ~ 15% of the feed carbon. More than half the liquids are mixed aromatics (BTX, benzene-toluene-xylene, gasoline blending stock); the balance is a mixture of phenol and naphthalene and is useful as a fuel oil. The nitrogen and sulfur in the peat are recovered in the gas cleaning section and sold as anhydrous NH_3 and solid sulfur.

The economics of the process for the production of SNG from Minnesota peat have been estimated by IGT and these cost estimates will be briefly reported below.

Medium-Btu Fuel Gas. The schematic flow diagram for the production of medium-Btu gas is shown in Plate 4-13. This scheme is similar to that for SNG production, except that CO-shift and acid-gas (CO_2, H_2S) removal will not be required. The operating conditions will otherwise be very similar to those discussed under SNG production. The heating value of the gas will be about 16.8 MJ/m^3 (450 Btu/ft^3). Similar yields of BTX, fuel oil and anhydrous ammonia are expected as in the case discussed previously.

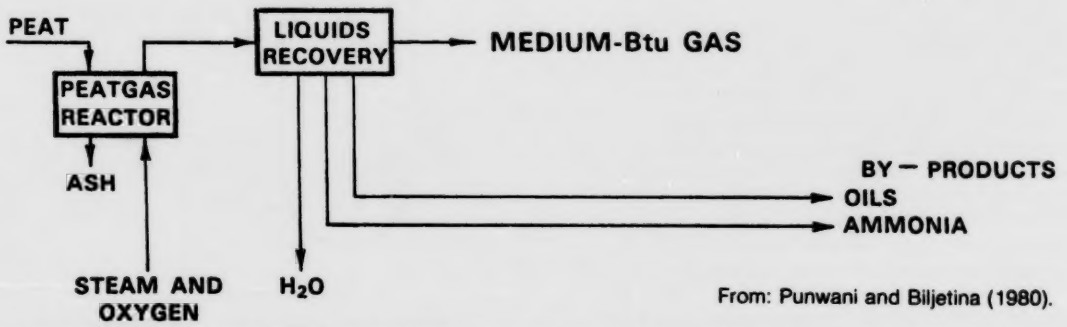
Synthesis Gas and Methanol. A conceptual flowsheet for the production of methanol is shown in Plate 4-14. For maximising methanol yield, the hydrogasifier stage is operated at about 540°C (1000°F). At this temperature, the direct yield of hydrocarbon liquids is about 28% of the feed carbon and the yields of synthesis gas (CO and H_2) and hydrocarbon gases are about 59% and 12% of the feed carbon, respectively. The carbon monoxide and hydrogen produced under these conditions can be converted to methanol by conventional techniques. The hydrocarbon gas produced may be either steam reformed to yield more CO and H_2, which can be used for producing more methanol, or used as a by-product gas. The synthesis gas may be subjected to Fischer-Tropsch synthesis to yield a mixture of products characteristic of that route.

No preliminary design or economic evaluation of either medium-Btu gas or methanol synthesis has been carried out by IGT to date.

MASS AND ENERGY BALANCE. A series of preliminary design calculations have been carried out by IGT, using laboratory and PDU scale kinetic data, to estimate the economic feasibility of the process and to choose among possible process alternatives. The summary presented in Table 4-12 reflects the result of pre-drying the peat to 35% moisture content prior to feeding it into the reactor drying stage. It was shown (IGT Interim Report 8, 1980) that this approach is more cost-effective than feeding the peat at 50% into the reactor dryer stage.

It was also shown in the same report that North Carolina peat will give rise to a slightly different product distribution and thermal efficiency from those projected for the less humified Minnesota peat. Only the figures calculated for Minnesota peat are presented in this report.

The overall thermal efficiency for SNG production from Minnesota peat was 65.92%. The cold gas efficiency was 51.7%.



From: Punwani and Biljetina (1980).

PLATE 4-13. CONCEPTUAL FLOW SHEET FOR PRODUCTION OF MEDIUM-BTU GAS FROM PEAT BY THE PEATGAS PROCESS.

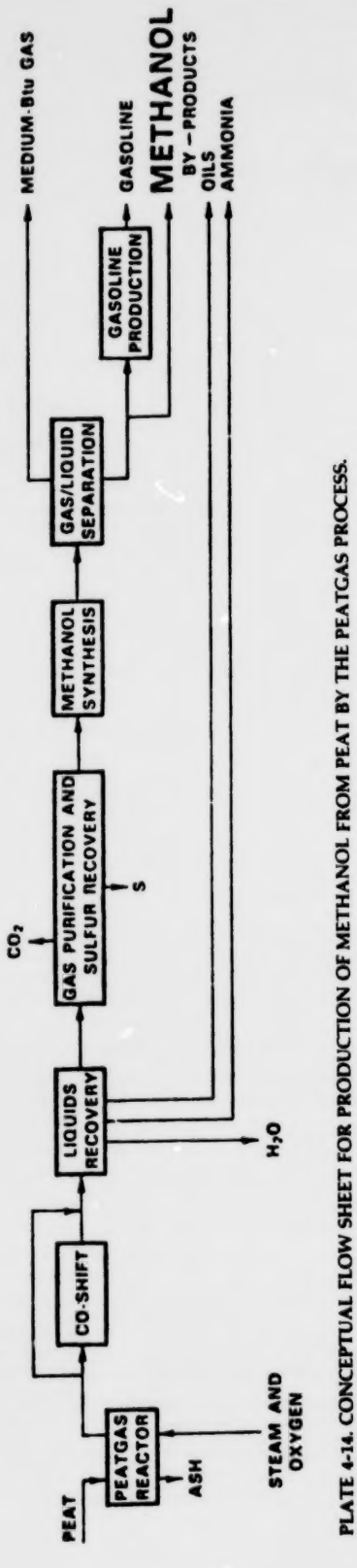


PLATE 4-14. CONCEPTUAL FLOW SHEET FOR PRODUCTION OF METHANOL FROM PEAT BY THE PEATGAS PROCESS.

For the production of 263.6 TJ/day (251 x 10^9 Btu/day) SNG, the feed requirement was 2.59 x 10^4 dry tonnes/day peat at 10.6 MJ/kg (8506 Btu/lb), dry basis (Table 4-13).

The composition of the product gas stream is shown in Table 4-13. Its heating value is shown as 43.63 MJ/m^3 (965 Btu/ft^3). The by-product compositions and heating values are shown in Table 4-12.

The PEATGAS plant is energy self-sufficient, generating all steam and power, including that needed for oxygen production.

TABLE 4-12. SUMMARY OF MASS AND ENERGY BALANCE FOR CONVERSION OF MINNESOTA PEAT TO 263,600 GJ/DAY PIPELINE GAS FEED PRE-DRIED TO 35% MC.

	GJ/h	% of Input peat
Input		
Peat to Gasifier, 810,643 kg/h (dry basis: 10.6 MJ/kg)	16,028.0	75.11
Peat Dryers, 79,171 kg/h (dry basis)	1,565.4	7.34
Peat to Boiler, 189,375 kg/h (dry basis)	3,744.3	17.55
Total Input 1,079,189 kg/h (dry basis)	21,337.5	100.00
Output		
Pipeline Gas (252,792 m^3/h 43.63 MJ/m^3)	11,031.1	51.70
Benzene (501,606 ℓ/day x 37.13 MJ/ℓ)	775.8	3.64
Oil*–a mixture of C_6H_6, C_6H_6O, and $C_{10}H_8$ (1,007,315 ℓ/day at 42.10 MJ/ℓ)	1,767.1	8.28
Ammonia (501.0 tonnes/day at 22.48 MJ/kg)	468.9	2.20
Sulfur (46.4 tonnes/day at 9.25 MJ/kg)	17.9	0.10
Subtotal,	14,060.8	
Overall Efficiency, %		65.92
Losses with Char, Water Cooling, Air Cooling, Flue Gases from Dryer and Boiler, Motive Power, and unaccounted for	7,276.6	34.08
Total Heat Out	21,337.5	100.00

	*Oil Composition			
	wt %	kg/h	kg/ℓ	MJ/kg
Benzene	11.31	5,139	0.877	42.33
Phenol	31.02	14,098	1.07	35.17
Naphthalene	57.67	26,206	1.14	40.20
	100.0	45,443	1.08	38.88

From: IGT Interim Report No. 8 (1980)

TABLE 4-13. COMPOSITION OF PRODUCT GAS STREAM FOR A PLANT PRODUCING 264,750 GJ/DAY SNG FROM MINNESOTA PEAT.

	Product Gas	
Temperature, °C	37.8	
Pressure, kPa	6996	
Component	**mol/h**	**mol %**
CO	29	0.10
CO_2	453	1.58
H_2	1,045	3.65
H_2O	4	0.01
CH_4	26,960	94.15
C_2H_6	—	—
NH_3	—	—
H_2S	—	—
N_2 + Ar	144	0.51
C_6H_6	—	—
C_6H_6O	—	—
$C_{10}H_8$	—	—
Total	28,635	100.00

From: IGT Interim Report No. 8 (1980)

Total water circulation rate in the plant is 485 m^3/minute (128,260 USGM). Plant makeup water requirement is 20.7 m^3/minute (5460 USGM), of which 14.8 m^3/minute (3911 USGM) would be supplied from an external raw water source. These requirements are for the process plant only. Miscellaneous uses could add another 3.8 m^3/min.

CAPITAL AND OPERATING COSTS. Factored cost estimates for a 265 TJ/day (250 x 10^9 Btu/day) SNG plant were prepared by IGT (Interim Reports No. 5 and 8). The design guidelines are shown in Table 4-14. Capital costs were based on early 1975 figures, to be updated by published cost indices.

Total installed cost of equipment, contingencies (15%), contractor charges, startup costs and working capital was U.S.$1045.4 million in early 1978 dollars. The Chemical Engineering plant cost index has advanced 27% by April, 1981, giving a current estimated capital requirement of U.S.$1327 million.

Revenue requirements were calculated according to the utility-type financing method using factors derived from the Synthetic Gas-Coal Task Force of the U.S. Federal Power Commission. Financial factors, annual operating costs and revenue requirements for Minnesota Peat are shown in Table 4-15. The 20-year average price for SNG was estimated to be U.S.$4.61/GJ (U.S.$4.84/10^6 Btu) based on U.S.$1.67/GJ peat cost, using early 1978 costs.

Sensitivity analyses were also carried out on a few major cost items: sensitivity to peat cost is a 2¢ change in gas price for a 1¢ change in peat cost; a 20% variation in plant cost changes the gas price by approximately 42¢/GJ; a change of 1¢/litre in the aromatic fuel oil value changes the gas price by 1.07¢/GJ (IGT Interim Report No. 5, 1979).

It is to be noted that the above costs are estimated values, based on a sophisticated analysis and extrapolation of PDU-scale data. The confidence in any projections will be enhanced by the release of the preliminary design report now being prepared by Dravo Corporation. Publication of this report is expected in March, 1982. Furthermore, the experimental demonstration of the process at IGT will have been under way by that time for close to a year.

IGT has prepared a process design program and a separate plant cost estimating program to allow preliminary design and costing of PEATGAS plants, based on lab-scale gasification tests of site-specific peat samples. These programs are available for the preparation of budget cost estimates for clients outside IGT.

ENVIRONMENTAL CONSIDERATIONS. The plant will be designed to meet the emission standards given in Table 4-14.

Waste water will be treated by established technology, provided by the Chevron Research Company, a subsidiary of Standard Oil of California.

For the treatment of low-H_2S-content process gas, a package unit of the Stretford sulfur recovery process will be used.

The environmental impact of large-scale milled peat production will be addressed in Part 6 of this report.

ASSESSMENT. The PEATGAS process is subject to intensive process development effort. A ~ 2 tonnes/hour (dry peat) demonstration plant is being operated by IGT. The results of this work and a feasibility study for an 84 TJ/day SNG plant will be available about March, 1982.

In the meantime, a preliminary capital and operating cost estimate shows that, on the basis of 265 TJ/day production, starting with U.S.$1.67/GJ milled peat cost, substitute natural gas may be produced at the 20-year average cost of U.S.$4.61/GJ, using early 1978 costs. This figure (even with the cost escalation of the intervening years) is attractive compared to the projected cost of coal-derived SNG (roughly U.S. $7.50/GJ, 1980). It is however, higher than the present cost of natural gas in Ontario (C$3.25/GJ).

TABLE 4-14. SUMMARY OF GUIDELINES FOR THE PROCESS DESIGN AND COST ESTIMATE FOR A 263,600 GJ/DAY SNG FROM PEAT PLANT.

Plant Capacity, TJ/day SNG	264
Plant Annual Stream Factor, %	90
Plant Location	Minnesota
Product Specifications	
HHV, MJ/m^3	> 42.0
CO, %	0.1
H_2O, kg/10^6 m^3	136.2
H_2S, g/100 CF	Trace
Pressure, kPa	6895
Temperature, °C	37.8
Typical Peat Analysis (dry), wt %	
C	49.90
H	3.09
O	30.71
N	2.73
S	0.27
Ash	11.30
HHV	8506
Cost of Milled Peat Received at Plant, $/GJ	71.0¢/GJ To be treated as variable, 0.48 to 1.67
Plant Input	Peat, makeup water, catalyst and chemicals; no purchased utilities
Water Supply	If peat is dewatered mechanically, this may supply much of the plant makeup; if any is purchased, the cost is 13.2¢/1000 ℓ
Cooling Water	27°-46°C by cooling towers. Summer wet bulb, 21° C
Plant Financing	Utility type financing 75% debt at 9% interest, 25% equity at 15% return, 20-yr plant life, straight-line depreciation, 48% Federal income tax
Plant Cost	Factored estimate of process design and equipment specs; early 1975 costs; published cost indexes will be used to update applicable earlier cost data
Operating Labor, $/h	7.50
Maintenance, % of installed plant	3
Other Operating Costs and Revenue Requirements	Method of synthetic gas-coal task force for utility method SNG = $/GJ
By-Product Credits	
Sulfur	$25.4/tonne
Ammonia	$90.7/tonne
B-T-X	15.9¢/ℓ
Crude Aromatic Oils	8.0¢/ℓ base cost
Plant Thermal Efficiency	$100 \times \frac{\text{Total MJ in SNG} + \text{By-products}}{\text{Total MJ in Peat Input}}$
Sensitivity	Effect of variations in peat cost, plant cost, and aromatic oils cost
Emission Standards	
H_2S	None emitted
SO_2	Max 0.27 kg/GJ HHV of solid fuel or 90% removal to max of 0.09 kg/GJ
NO_x	Not determined
Wastewater	Cleaned and used as cooling tower makeup

Costs in U.S. dollars
Peat received at plant contains 50% moisture
By-product credits reflect April, 1978, prices
From: IGT Interim Report No. 5 (1979)

TABLE 4-15. ANNUAL OPERATING COSTS AND REVENUE REQUIREMENTS FOR SNG FROM MINNESOTA PEAT: 264,640 GJ/DAY, 90% STREAM FACTOR; UTILITY FINANCING; 20-YEAR PLANT LIFE, STRAIGHT LINE DEPRECIATION, 75-25 DEBT-EQUITY; UTILITY FINANCING - REVISED GUIDELINES FOR MAINTENANCE AND LOCAL TAXES (COST ESTIMATES OF APRIL 1978, IN US $).

	Annual Costs ($1000's)		
Peat			
¢/GJ	71	48	167
$/year	119,664.6	79,775.9	279,217.4
Catalysts and Chemicals		3,193.5	
Purchased Water, 13.2¢/m^3		894.0	
Labor			
Operating, $7.50/hr, 65 persons/shift		4,270.5	
Supervisory, 20%		854.1	
Administrative and Overhead, 60%		3,074.8	
Supplies, 30% of Operating Labor		1,281.2	
Total Maintenance, 3% of T.P.I.		24,762.0	
Local Taxes and Insurance, 1.5% of T.P.I.		12,381	
Total Gross Operating Costs	170,375.7	130,487.0	329,928.5
By-Product Credits ($1000's)			
B.T.X., 10.6¢/ℓ 17,412			
Ammonia, $90.7/tonne 18,133			
Sulfur, $25.4/tonne 375			
Oils, 7.9¢/ℓ 26,225			
62,145		-62,145	
Net Operating Cost	108,230.7	68,342.0	267,783.5
Depreciation		50,320.0	
Return on Rate Base, 20-yr avg	56,942	55,997	60,701
Federal Income Tax, 20-yr avg	18,772	18,460	20,010
Annual Revenue, 20-yr avg	234,264.7	193,119.0	398,814.5
Annual SNG, GJ		86,969,114	
20-Year Avg Price of SNG, $/GJ	2.70	2.23	4.61
$/$10^6$ Btu	2.84	2.34	4.84

From: IGT Interim Report No. 8 (1980)

The economics of the PEATGAS process should be evaluated with reference to Ontario conditions in Phase II of this study. This evaluation should consider these process configurations:

- the production of SNG from milled peat
- the production of methanol from milled peat using the PEATGAS process for synthesis gas production
- the possible benefits of providing hydrogen from an external source for both SNG and syngas production.

In order to carry out the above, the following information needs to be obtained:

- more accurate process and cost data from IGT regarding the proposed process trains
- a mine site of the required size to be selected in Ontario, and production costs developed for the production scale envisioned
- process kinetics data for Ontario peat to be developed by standard methods available at IGT
- market size and price trend predictions for SNG and methanol.

PEATGAS promises to be a major consumer of fuel peat in the U.S. within five years. It is recommended that its potential for Ontario be evaluated as Phase II of this study.

4.5.2.5 CITIES SERVICE/ROCKWELL (CS/R) ADVANCED PEAT HYDROGASIFICATION PROCESS

The Cities Service Research and Development Company, together with the Energy Systems Group of Rockwell International are currently developing an advanced coal-fired SNG hydrogasification process. This work has advanced to the point where peat is also being examined as feedstock for the process.

The work summarised in this section (Sprouse *et al.* 1980) reports the results of pilot plant tests which have extended the existing peat hydrogasification kinetics database to feed rates a hundred times higher than previously tested and to higher reactor temperatures and pressures. These data were used to carry out preliminary design studies of three alternate process flowsheets, and to estimate the capital, operating and product costs for these.

CURRENT STATE OF DEVELOPMENT. Hydrogasification tests were carried out in a pilot reactor at a peat throughput of 16 tonnes/day. The tests have been conducted at high hydrogen partial pressures (3.5-10.7 MPa) and temperatures (860-1015°C). The carbon conversion data were combined with others' results obtained at milder conditions, and a relatively simple peat hydrogasification reactor kinetic model was developed, which gave a consistent correlation of experimental data within the operating ranges of: reaction temperatures from 454-1010°C (850-1350°F), hydrogen partial pressure from 0 to 10.2 MPa (0-1500 psi) and reactor residence times from 0.50 to 7.7 seconds.

This model was then used to design the hydropyrolysis reactor of an approximately 264 TJ/day (250 x 10^9 Btu/day) SNG plant, based on Minnesota peat. Other necessary unit processes were added (based mainly on IGT's preliminary designs) to complete the plant design estimates.

The emphasis of the design exercises was on maximising BTX (mixed aromatics: benzene, toluene, xylene) production, since, at the market price of US$1.55/gallon (mid-1980), it is a significant contributor to revenues. Test results showed that, for moderate residence times (1-4 seconds) BTX production was maximised between 870-927°C reactor temperature.

Work on peat hydrogasification will continue later in 1981. This will consist of further experimental runs to refine hydrogasification kinetics and the performance of more accurate preliminary process design estimates (K. M. Sprouse, personal communication). The program, to date, has been funded by the U.S. Department of Energy.

FEED CHARACTERISTICS. All three plant design case studies described below assume milled peat containing 50% moisture being received at the plant site. The experimental runs have been carried out using Minnesota peat. No comparison with the performance of other peat types has been published. Noting the analogy of the process with PEATGAS, one would expect differences in plant costs and performance if other than Minnesota peat were to be used.

PROCESS DESCRIPTION. Three process flowsheet alternatives were evaluated from the points of view of mass and energy balance, capital and operating costs and product revenue requirements. They differ in their method of generating makeup hydrogen gas and hydrogasifier operation. These distinguishing aspects will be described first, followed by the features common to all three case studies. The designs are based on hydrogasifier performance data obtained in two test runs, as shown in Table 4-16.

The first two plant configurations are based on Run 300-047, operating at a hydrogasifier pressure of approximately 3.55 MPa (500 psig), a reaction temperature of 922°C and a relatively high weight ratio 10.529) of hydrogen gas to peat. A preburner method of injection was used in which hydrogen and oxygen are reacted in a recessed chamber to obtain a gas temperature of approximately 1370°C prior to

TABLE 4-16. REACTOR TEST CONDITIONS FOR ECONOMIC STUDY.

Conditions	Run 300-047 Preburner	Run 318-049 O_2 Face Injection
Temperature (°C)	877	941
Pressure (MPa)	3.34	3.34
H_2/Peat (kg/kg)	0.529	0.171
Residence Time(s)	1.32	3.31
Peat Moisture (wt %)	9.40	9.21
Carbon Conversions		
Wt % to C_6H_6	10.2	6.5
Wt % to C_7H_8	0.0	0.1
Wt % to CH_4	38.7	34.8
Wt % to CO	24.1	28.2
Wt % to CO_2	1.5	3.7
Wt % to C_2H_4	0.2	0.1
Wt % to C_2H_6	1.9	0.9
Wt % Total	76.6	74.3

From: Sprouse *et al.* (1980)

mixing with peat in the reactor. The primary source of hydrogen for the hydrogasifier is the recycle after cryogenic separation from the main process stream. However, a small portion (approximately 5.1%) of the hydrogen gas feed must be generated by a separate process.

The first plant design, shown in Plate 4-15, uses a partial oxidation gasifier to generate the required makeup hydrogen. Char and peat are reacted with steam and oxygen to produce synthesis gas (CO + H_2). The CO is reacted with steam in a CO-shift reactor to produce more H_2. The acid gases (CO_2 and H_2S) are removed from this stream with scrubbers. This makeup stream is then combined with the cryogenically separated hydrogen stream, compressed to 3.76 MPa (530 psig) and preheated to 815°C (1500°F) prior to injection into the hydrogasifier.

The second plant design, as shown in Plate 4-16, uses steam reforming of a portion of the plant product SNG to generate the makeup hydrogen. The gas from the reformer is further enriched in hydrogen by shifting the CO present in this stream with steam. The makeup hydrogen produced is combined with the recycled hydrogen stream as in the first plant design.

The third plant configuration is based upon Run 318-049, given in Table 4-16. In this design, an injector feeds oxygen directly to the hydrogasification reaction chamber through its face. This plant design, as shown in Plate 4-17, uses a partial oxidation unit to produce the required makeup hydrogen. This partial oxidation unit is similar to that of the first plant configuration but does not require any fresh peat for this unit since more than enough char is produced in the hydrogasifier. The following units are common to all three flowsheets.

Feed peat is ground to 90% through a 200 U.S. sieve size in a hammermill, through which 205°C inert gas is introduced to dry and convey it to intermediate storage bins at 9.4% moisture. The drying gas consists of N_2 from the oxygen plant and CO_2 from the process air (if required).

Movement of the peat from the storage bins into the low-pressure charge vessels, high-pressure lock hoppers, and reactor feed vessels takes place intermittently during a controlled sequence of cycles by means of dense-phase solids-gas flow. CO_2 is the transport gas for transfer from the low-pressure charge vessel to the high-pressure lock hopper. Hydrogen is used as the transport gas from the high-pressure lock hopper to the reactor feed vessel.

Dried peat, oxygen (99.5% O_2 at 154°C) and feed hydrogen are continuously fed to the hydrogasification reactors where the very rapid hydropyrolysis reactions convert approximately 74 to 77% of the peat carbon into gaseous and liquid products. The liquid product consists almost exclusively of benzene with a trace of toluene. The gases produced are chiefly CH_4, CO and water with some C_2H_4, C_2H_6, CO_2, H_2S and NH_3. The unreacted carbon and mineral matter from the peat constitute a fine dry char which is carried out of the reactor with the gases.

The gas is subsequently cooled while preheating the feed hydrogen. The char is removed via a series of cyclone separators. It is then enriched in hydrogen via the CO-shift reaction. The gas is scrubbed with water to remove H_2S and NH_3. Next, the CO_2 is stripped from the gas stream. The product gas is then passed through a straw oil scrubber which removes benzene and other liquid hydrocarbons. The benzene is further purified by the Pyrotrol process.

The gas from the benzene absorber is dried on a molecular sieve bed. This dried gas is then passed through a cryogenic separation system. The two streams arising from this system are a recycle gas containing 99.7% of the inlet hydrogen and a methane rich pipeline gas compressed to 7 MPa (1000 psig) before introduction into the pipeline.

MASS AND ENERGY BALANCE. The material requirements and product flows are shown in Table 4-17.

TABLE 4-17. PLANT MATERIAL REQUIREMENTS AND PRODUCTS.

Material	Case 1	Case 2	Case 3
Material Inputs			
1. Peat (50% Moisture), total tonne/day	67,627	71,265	64,921
a. To Hydrogasifier	32,789	54,169	40,721
b. To Boiler and Superheater	30,767	17,096	24,200
c. To P.O. Gasifier	4,080	—	—
d. HHV at 50% Moisture, MJ/kg	9.68	9.68	9.94
2. Oxygen, total tonne/day (99.5% O_2)	8,162	5,363	8,056
a. To Hydrogasifier	3,246	5,363	3,133
b. To P.O. Gasifier	4,916	—	4,923
3. Makeup Water, ℓ/min	48,706	42,051	41,203
Products			
1. Pipeline Gas, m^3/day	5.97×10^6	5.85×10^6	6.18×10^6
HHV, MJ/m^3	44.36	44.95	44.27
HHV, GJ/day	264,642	263,588	274,131
2. Benzene, ℓ/day	1,093,742	1,807,416	819,564
ℓ/day	820,350	1,355,605	614,667
3. Ammonia, tonne/day	289	477	516
4. Sulfur, tonne/day	36.6	37.6	29.5
5. Ash, tonne/day	6,426	6,772	4,537
6. Toluene, ℓ/day	0	0	13,010

From: Sprouse *et al.* (1980)

The energy balances for all three case studies are given in Table 4-18. The thermal efficiency is defined as:

$$100 \times \frac{\text{heat content of saleable products}}{\text{heat content in peat feed}} = \eta, \%$$

All electrical power and steam is generated within the plant. Makeup water requirement is shown in Table 4-17. Sprouse *et al.* (1980) state that the plant energy outputs accounted for were within 6% of energy input. This is probably not unreasonable, considering the level of detail of this study. The plant thermal efficiencies have an estimated accuracy of ±5%.

CAPITAL AND OPERATING COST ESTIMATES. As the scope of the study was limited, considerable use was made of previously completed plant design estimates, such as the IGT PEATGAS designs (IGT Interim Reports Nos. 5 and 8), a plant design study conducted by Scientific Design Company Inc. for Rockwell of a coal hydropyrolysis plant using the CS/R process, and a design study of a steam-methane reforming system conducted by the Foster-Wheeler Corporation for Cities Service and Rockwell.

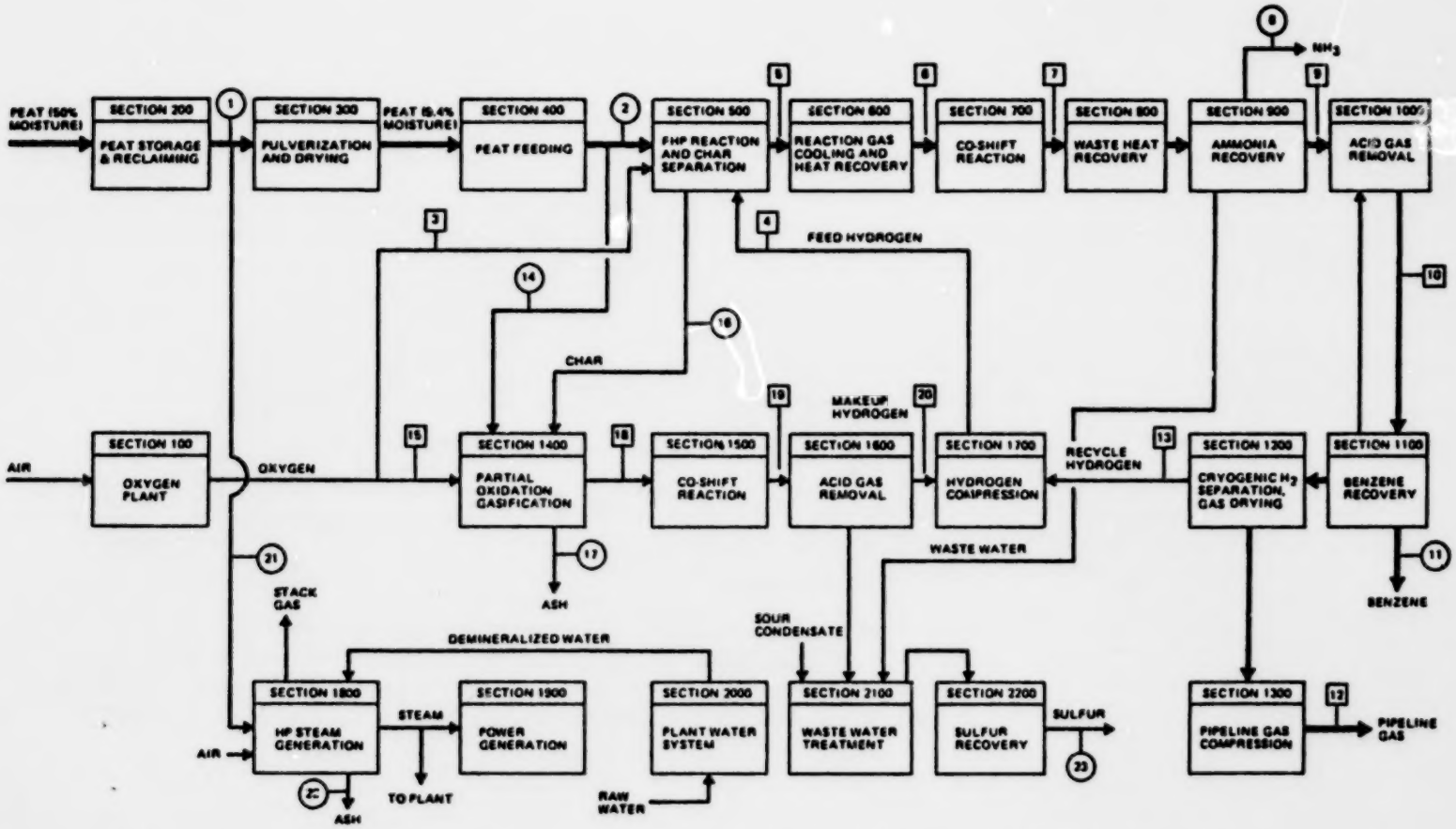


PLATE 4-15. PEAT HYDROGASIFICATION PROCESS CASE 3. (MAKEUP HYDROGEN SUPPLIED BY PARTIAL OXIDATION GASIFIER WITH THE HYDROGASIFIER PERFORMANCE BASED ON RUN 318-049)

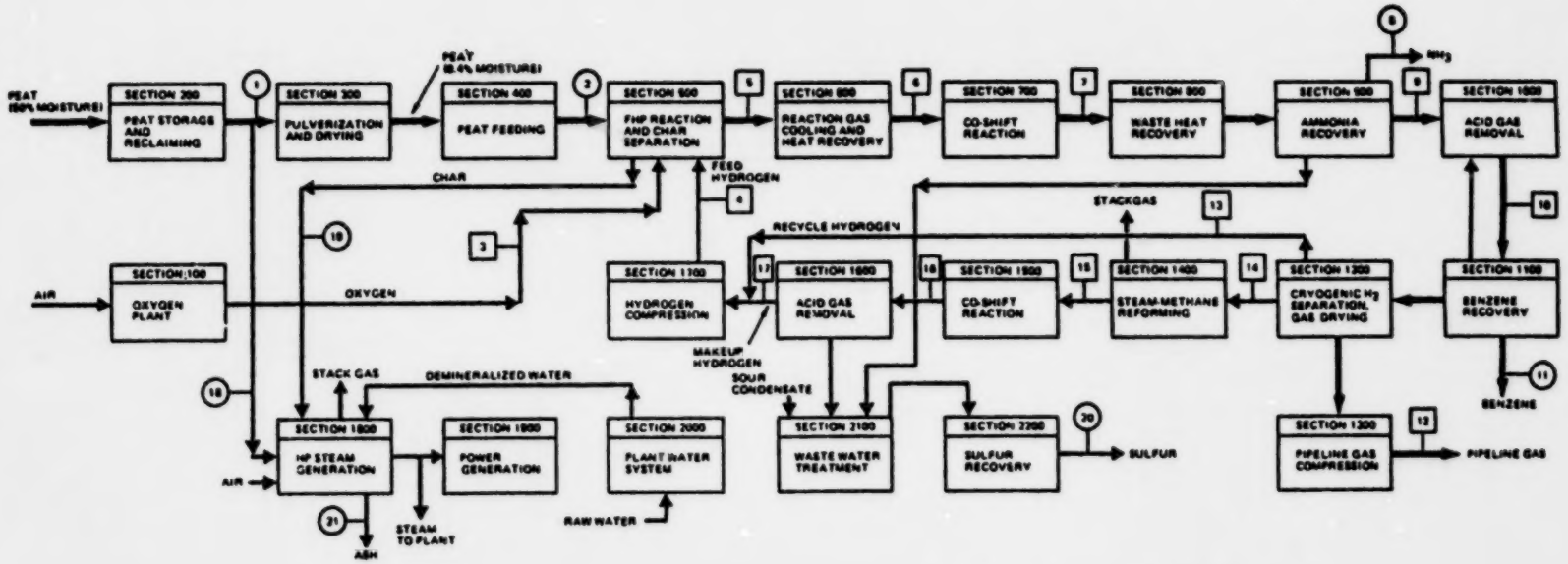


PLATE 4-16. PEAT HYDROGASIFICATION PROCESS CASE 2. (MAKEUP HYDROGEN SUPPLIED BY STEAM-METHANE REFORMING WITH THE HYDROGASIFIER PERFORMANCE BASED ON RUN 300-047).

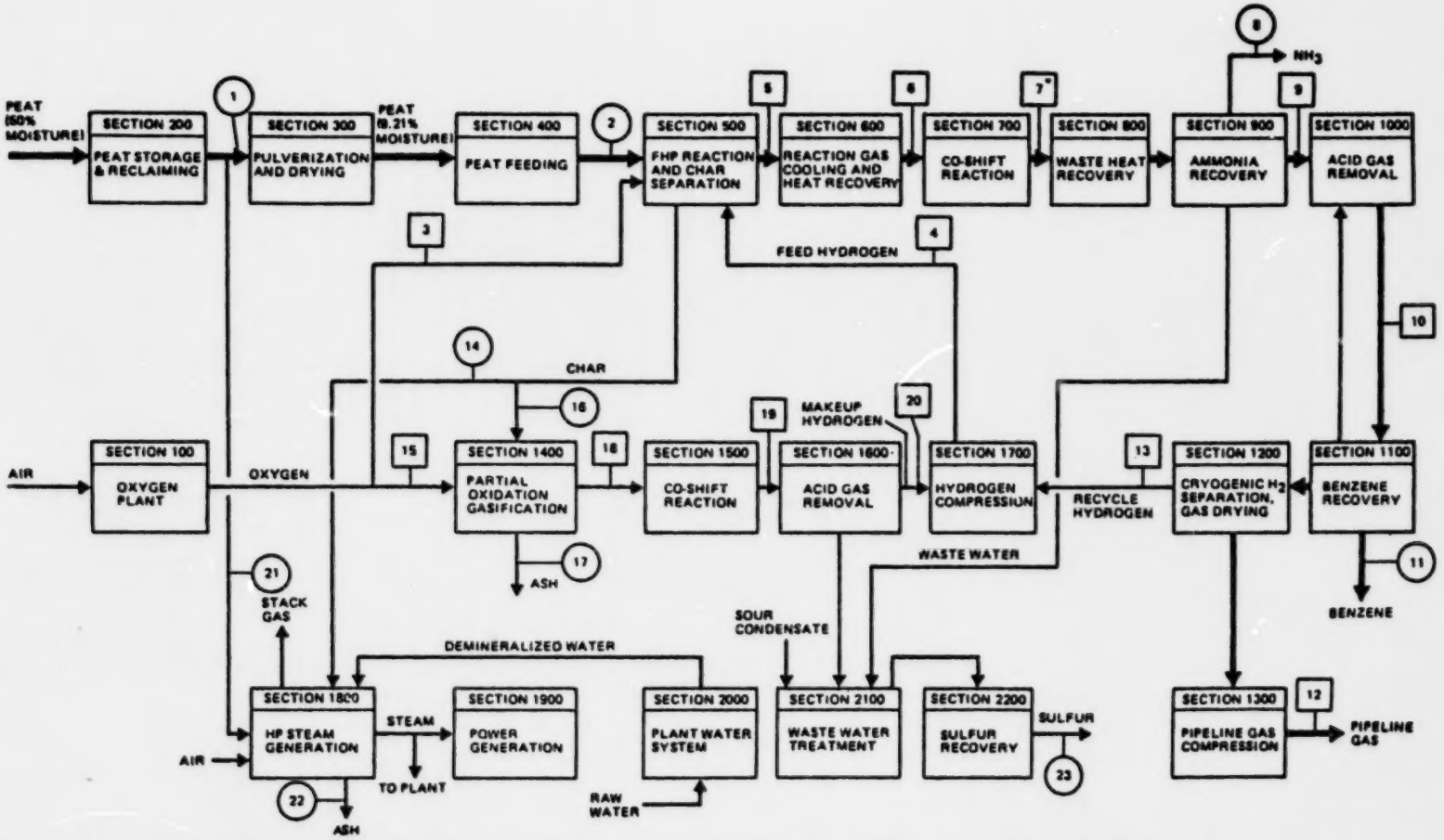


PLATE 4-17. PEAT HYDROGASIFICATION PROCESS CASE 1. (MAKEUP HYDROGEN SUPPLIED BY A PARTIAL OXIDATION GASIFIER WITH THE HYDROGASIFIER PERFORMANCE BASED ON RUN 300-047).

TABLE 4-18. PLANT ENERGY BALANCE.

Energy Usage	Case 1 GJ/day	Case 1 %	Case 2 GJ/day	Case 2 %	Case 3 GJ/day	Case 3 %
Energy In						
Heat Content of Peat	654,555	100.000	689,772	100.000	645,558	100.000
Energy Out						
Saleable Products						
Pipeline Gas	265,438	40.552	263,588	38.214	274,257	42.484
Benzene + Toluene	40,608	6.204	67,106	9.729	30,911	4.789
Ammonia	6,493	0.992	10,736	1.557	11,605	1.798
Sulfur	335	0.051	346	0.050	269	0.042
Waste Heat						
Boiler and Superheater Stack Gas	81,567	12.461	53,973	7.824	37,631	5.829
Reformer Stack Gas	—	—	16,221	2.351	—	—
Heat Rejected to Water Cooling	186,130	28.436	205,086	29.732	173,350	26.853
Heat Rejected to Air Cooling	61,343	9.372	93,905	13.614	72,801	11.277
Ash Heat Content	9,522	1.455	4,655	0.675	5,900	0.914
Miscellaneous	3,120	0.477	(25,840)	(3.746)	38,833	6.014
Total	654,555	100.000	689,772	100.000	645,558	100.000
Plant Cold Gas Efficiency (%)	**40.55**		**38.21**		**42.48**	
Plant Thermal Efficiency (%)	**47.80**		**49.55**		**49.11**	

From: Sprouse *et al.* (1980)

Scaled costs were escalated using the Chemical Engineering Plant Cost Index to the first quarter of 1980. Since that time, the Index has advanced 12.8% to April, 1981. Table 4-19 shows the total capital requirements.

TABLE 4-19. 20-YEAR AVERAGE GAS COST COMPARISON (10^6 US$, APRIL, 1980).

Cost Breakdown[1]	Case 1	Case 2	Case 3
Total Capital Requirement (10^6 $)	2072	2347	1866
Annual Net Operating Cost (10^6 $)	85.40	−1.42	98.93
Capital Contribution to COG[2] ($/GJ)	2.89	3.29	2.50
Operating Cost Contribution to COG ($/GJ)	0.98	−0.02	1.10
	3.88	3.27	3.60

[1]Based on (a) 20-year project life
(b) 20-year straight line depreciation
(c) Debt-equity ratio of 75/25
(d) 9% interest on debt
(e) 15 return on equity
(f) 48% Federal income tax

[2]COG: Cost of Gas

From: Sprouse *et al.* (1980)

TABLE 4-20. ANNUAL OPERATING COST BREAKDOWN (10^6 US$, APRIL, 1980).

Operating Costs, 90% on stream	Case 1	Case 2	Case 3
Peat ($0.71/GJ)	152.95	161.18	150.85
Catalysts and Chemicals	4.55	4.80	4.37
Purchased Water ($0.13/1000 ℓ)	3.04	2.63	2.57
Operating Labor (75 men/shift at $10/h)	6.57	6.57	6.57
Supervision (20% of operating labor)	1.31	1.31	1.31
Administration and General Overhead (60% of total labor)	4.73	4.73	4.73
Operating Supplies (30% of operating labor)	1.97	1.97	1.97
Maintenance (3% of TPI)	49.15	55.68	44.27
Local Tax and Insurance (1.5% of TPI)	24.58	27.84	22.13
Ash Disposal ($90.7/tonne)	2.33	2.45	1.64
Gross Operating Cost	251.18	269.16	240.41
Benzene Credit ($0.41/ℓ)	147.12	243.12	111.99
Sulfur Credit ($53.9/tonne)	0.63	0.65	0.51
Ammonia Credit ($140.6/tonne)	18.03	26.81	28.98
Total By-product Credits	165.78	270.58	141.48
Net Operating Cost	85.40	−1.42	98.93

From: Sprouse *et al.* (1980)

Annual plant operating costs are shown in Table 4-20. Peat cost was assumed at U.S.$0.71/GJ, which is lower than the minimum milled peat cost calculated for Ontario (C$1.63/GJ) in Part 3 of this study. These costs were determined at a considerably smaller scale of production, viz ~ 150,000 tonnes/yr.

20-year average revenue requirements were calculated on the basis of utility-type financing. The financial assumptions and gas cost comparisons are shown in Table 4-19.

ENVIRONMENTAL CONSIDERATIONS. The process design estimates were aimed at satisfying the same emission standards as shown for the PEATGAS process.

Acid gas and NH_3 are removed from the scrubber water using the Chevron wastewater treatment process. Three streams are produced: anhydrous liquid ammonia, acid gas (CO_2 and H_2S) and, virtually, pure water. The acid gas is sent to sulfur recovery, where the latter is collected in the solid form, employing the Stretford process. The ammonia is sent to storage, and the water is used in the cooling circuits.

The effects of large-scale milled peat harvesting operations are addressed in Part 6 of this work.

ASSESSMENT. The experimental work is targeted at the thorough exploration of the hydrogasification unit process. Other unit operations are piloted at IGT, and there is evidence of close co-operation between the two groups. It is to be expected, therefore, that the development of CS/R Hydrogasification and PEATGAS will continue concurrently and may be commercial in the mid-eighties.

CS/R Hydrogasification achieves SNG costs which are somewhat lower than those attained by PEATGAS, due to the higher yield of BTX in the former. Capital investment is significantly higher for CS/R, and the thermal efficiency is lower than in the case of PEATGAS.

In order to forecast the potential of the process for Ontario, it will be necessary to obtain peat production costs on the scale required here and to explore the economics which would arise if cheap, electrolytically produced hydrogen were to be used for hydrogasification.

4.5.3 LIQUEFACTION

4.5.3.1 GENERAL

Recent increases in energy cost have revived the interest in synthetic liquid fuel production. Once considered to be economically unattractive, various routes of liquefaction of solid fuels are currently under investigation.

The two principal routes to synthetic liquid fuels from solid fuels are direct and indirect liquefaction.

In direct liquefaction (or hydrogenolysis), peat in its raw (wet) state is treated under high pressures (up to 30 MPa) for short periods of time (few minutes) in the presence of a reducing atmosphere (CO/H_2) at a temperature of 300-350°C (Chornet and Roy, 1980). The liquid produced, known as bitumen, is similar to very heavy oil. It is fluid at slightly elevated temperatures, and it can be utilized as a fuel directly or after additional hydrogenation (Björnbom and Granath, 1980).

In indirect liquefaction, the process consists of two steps: gasification to produce synthesis gas and from that, liquid fuel through catalytic routes. The liquid fuels produced in this type of process are methanol or hydrocarbons via the Fischer-Tropsch synthesis.

A proposed commercial venture for producing 614 tonnes/day methanol from milled peat, using Koppers-Totzek gasification technology, will be briefly described next.

4.5.3.2 INDIRECT LIQUEFACTION

PEAT TO METHANOL PROJECT, NORTH CAROLINA. A consortium of companies and investors, known as Peat Methanol Associates, have prepared a feasibility study for the production of 614 tonnes/day (202,010 tonnes/yr) methanol from milled peat to be supplied by First Colony Farms, Creswell, N.C. Construction will start in 1982, and production will begin in 1984.

Corporate members of the consortium are: Energy Transition Corporation (Santa Fe, NM) are project managers and KBW Gasification Systems Inc. (Pittsburgh, PA) supplies Koppers gasifiers and constructs the plant. KBW is jointly owned by Koppers and Babcock and Wilcox.

The economic evaluation carried out by Energy Transition Corporation showed a 16% internal rate of return after taxes, based on a projected 1984 capital investment of U.S.$253.8 million and a U.S.$12.14/tonne (1984) milled peat cost, solar dried to 30% moisture, 613,300 tonnes/yr, produced during a 160 day production season. Operating costs (excluding feedstock) were projected to be U.S.$0.23/gal methanol (1984). The only government assistance requested was a price guarantee of U.S.$0.75/US gal (1981). The financial analysis takes into consideration the tax position of the investors. Therefore, it is not detailed here. However, Energy Transition Corporation will undertake feasibility studies on behalf of clients (R.L. Schneider, personal communication).

A combination of factors make this project feasible: (a) First Colony Farms have developed large-scale mining equipment; (b) the annual milled peat production season in North Carolina is about 160 days long; (c) the climatic conditions in North Carolina allow solar drying to ~ 30% moisture; and (d) the materials handling and feeding equipment connected with the Koppers-Totzek gasifier has been modified to allow the feeding of peat. Methanol synthesis from the K-T synthesis gas will proceed via conventional (Pullmann-Kellogg) technology.

To evaluate this processing route in an Ontario context, it will be necessary to develop peat harvesting costs on the appropriate (large) scale of production, to examine the market and cost trends for methanol in the automotive fuel sector, and to examine closely the proposed technology. Furthermore, the economic and technical feasibility of using electrolytically produced hydrogen in the peat-to-methanol processing route should also be investigated.

4.5.3.3 DIRECT LIQUEFACTION

Direct liquefaction of peat is being investigated at the Royal Institute of Technology (RIT) in Sweden (Björnbom *et al.* 1980) and at the University of Sherbrooke in Quebec (Cavalier and Chornet, 1977).

ROYAL INSTITUTE OF TECHNOLOGY. Experimental work at RIT has been aimed at determining the suitability of Swedish peat as a raw material for direct liquefaction (Panayotova-Björnbom *et al.* 1979). Studies have been conducted using a 1 ℓ batch reactor. Reactor operating conditions—temperature, initial CO pressure, and amount of catalyst (K_2CO_3)—were varied to determine the effect on bitumen yield. It was determined that the best temperature is 350°C, and an initial CO pressure of 5.5-8.3 MPa. The presence of a catalyst is not always needed (Björnbom and Granath, 1980).

Bitumen yields achieved were approximately 20 weight % bitumen on a moisture and ash free basis (m.a.f.) equivalent to 39% thermal efficiency.

UNIVERSITY OF SHERBROOKE. Direct liquefaction work at the University of Sherbrooke clearly indicates that the conversion of peat into bitumen-like material can be conducted in the presence of water (Chornet and Roy *et al.* 1980). Here, as at RIT, a 1 ℓ batch autoclave is used for experimentation (Klenneman and Chornet, 1981). Here, again, optimum bitumen yields and overall peat conversions are obtained at operating temperatures of about 350°C. Operating pressures in the range of 30-40 MPa were employed (Chornet, 1980). Bitumen yields of 50-60% were consistently obtained.

It was found that alkali carbonates had a definite role in the reactions with weakly humified peat but this role was not as well defined for well humified peat.

Future work will focus on finding inexpensive and simple catalysts for the reactor.

4.5.4 OTHER PROCESSES

A number of other processes are being investigated for the conversion of peat to another fuel form. These processes include: pyrolysis, hydrolysis and electrochemical gasification.

4.5.4.1 PYROLYSIS

Pyrolysis is the process by which organic material, such as peat, is heated in the absence of oxygen, producing coke, a number of light products (of which the main ones are tar, methanol, ammonia and acetic acid), and gases (such as H_2, CO, CO_2, CH_4 and others). Pyrolysis reactions occur in the initial stage of gasification, but there the tars, liquid products and char are further reacted to form chiefly gaseous products. In pyrolysis per se, the liquid and solid products would be collected and further processed separately. The main obstacle to the large-scale industrial use of the pyrolysis process is quite simply the large number of diverse products gained.

Vacuum pyrolysis of previously dewatered and dried peat has been studied at the University of Sherbrooke (Chornet and Roy, 1980). The work has been carried out on a continuous flow reactor treating between 1 and 10 kg/min of peat. The material is heated in a three zone furnace at rates in excess of 10°C/min under low vacuum conditions and

high pumping speeds. This results in the breakdown of the peat with substantial release of condensible organic vapours and gases as well as the residual solid char. Organic liquid yields of 20 to 25% (m.a.f. peat) have been obtained.

4.5.4.2 HYDROLYSIS

Ethanol can be produced by fermentation of sugars obtained by hydrolysis of carbohydrates. The carbohydrate content of peat can vary, up to 40%. The two carbohydrates found in peat are cellulose and hemicellulose.

The cellulose and hemicellulose found in peat can be hydrolyzed with mineral acids to sugars. These sugars can then be fermented to ethanol. 45% conversion of peat to sugars was obtained in studies carried out at the University of Arkansas (Cahill and Gaddy, 1981).

Preliminary economic analyses indicate that the cost of ethanol from this process does not appear to be economical at present alcohol prices.

4.5.4.3 ELECTROCHEMICAL GASIFICATION

Experimental investigations of the electrochemical gasification of peat are being conducted at the University of Connecticut (Couglin, 1980).

The half-cell reactions can be written as follows:

Anode:

$$C(s) + 2\ H_2O(L) \rightarrow CO_2(g) + 4\ H^+ + 4\ e^-$$

Cathode:

$$4\ H^+ + 4\ e^- \rightarrow 2\ H_2(g)$$

The net reaction is:

$$C(s) + 2\ H_2O(L) \rightarrow 2\ H_2(g) + CO_2(g)$$

The work involves the study of the anodic oxidation of peat and coal. The results of the preliminary investigation indicate that the hydrogen rich volatile matter is preferentially consumed and the reacted portion of the carbonaceous solid is enriched in fixed carbon as a result of the electrochemical reaction.

The peat in this study is used to depolarize the anode during water electrolysis. Such reaction reduces the expenditure of electrical energy at the expense of peat consumption during hydrogen production by water electrolysis.

4.6 BIOLOGICAL CONVERSION PROCESSES

4.6.1 GENERAL

Peat is a material of biological origin and, as such, contains a rich variety of organic compounds: polysaccharides, humic acids, lignins, lipids, etc., most of which can be converted by bacteria, fungi and yeasts to methane, carbon dioxide and other useful products. The common feature of all biological conversions is that they take place in dilute aqueous media (85-99% moisture), low temperatures (< 65°C) and at atmospheric pressure. However, bioconversions proceed much slower than chemical processes.

The motivation for the development of biological processes for peat conversion is twofold: wet-mined material may be used without dewatering and the waste water produced is environmentally innocuous and may be directly returned to the bog.

In order to make the peat more palatable to microbes and thereby increase the rate and extent of conversion, pretreatments such as comminution and alkaline or thermal hydrolysis or partial oxidation may be necessary. Adequate supply of inorganic nitrogen (C/N < 15) and phosphorus (C/P < 75) must also be present.

Of the products that may be prepared by the many schemes proposed (Le Duy, 1980), methane is the most significant, considering both the amount of development effort expended and the prospect of economic viability.

In a typical biological gasification scheme, peat (or biomass) containing 90-95% water is added on a continuous or intermittent basis at a loading of up to 16 g volatile solids/ℓ-day (1 lb/ft^3-day) and a retention time of up to 20 days. In a stirred reactor, (or digester), from which air is rigorously excluded, a mixed population of anaerobic bacteria effect the conversion of up to 50% of the organic carbon to a mixture of methane and carbon dioxide (~ 60/40 by volume). This is equivalent to a methane yield of 0.25 m^3/kg VS (4 scf/lb VS). The maximum theoretical methane yield is 0.52 m^3/kg VS, based on 0.56 kg total organic carbon per kg volatile solids, if all the organics are converted.

Minor amounts of hydrogen and hydrogen sulfide may also be formed. These are the same reactions that produce marsh-gas in peat bogs.

Anaerobic digestion technology has been in use for waste activated sludge treatment for about 100 years. Anaerobic digestion research and development is currently very active in the biomass conversion and waste treatment fields and it is reasonable to expect that new findings in these fields will quickly be applied to peat.

The major research problems consist of increasing the extent of carbon to methane conversion, and reducing the digester residence time from up to 20 days to a few hours. All of the biological conversion technologies to be described below are still in their early development stages, but the projected energy balances and economic studies show advantages over thermal gasification methods. Therefore, vigorous development of these processes is continuing.

Three methane-producing biological processes will be discussed in this chapter:

- Alkaline oxidative pretreatment of peat slurry followed by anaerobic digestion, under investigation at Dynatech R/D Company, Cambridge, Mass.
- BIOTHERMGAS™, a process being developed at IGT, which combines anaerobic digestion and thermal gasification of the residue for the total conversion of wet peat.
- Vyrmethane™, a small-scale process which recovers methane generated in situ from recirculating bog-water.

4.6.2 BIOGASIFICATION OF PEAT

The Dynatech R/D Company of Cambridge, Mass., has recently completed an experimental and economic feasibility study of a bioconversion process to produce pipeline-quality SNG from wet-mined peat. Funds for the two-year, $422,000 study came from the U.S. Department of Energy, Minnegasco and Northern Natural Gas Company.

4.6.2.1 CURRENT STATE OF DEVELOPMENT

In the feasibility study, a preliminary plant design (based on previous in-house work) was carried out and the sensitivity of the methane price to several technical and cost parameters was established. Concurrently with this, bench-scale experiments were performed, to establish actual process parameters.

Solubilization and partial oxidation kinetics were established in the batch mode and fermentation kinetics and process conditions in a continuous, laboratory scale fermentor (Ruoff *et al.* 1980). The tests were done on wet harvested reed-sedge peat at 92% moisture, collected from the Red Lake area of Minnesota.

4.6.2.2 PROCESS DESCRIPTION

The proposed process consists of five steps:

(1) Peat solids are solubilized in an alkaline medium (Na_2CO_3) to produce substituted phenols from lignin and soluble wood-sugars.

(2) The solubilized peat is subjected to partial wet oxidation, where the aliphatic side-chains of lignin monomers are oxidized to carboxylic and aldehydic groups, with the aromatic rings remaining intact. These steps may be carried out in a single pretreatment reactor.

(3) Unreacted solids are separated by sedimentation, dewatered and used as fuel.

(4) Anaerobic fermentation of the solubilized peat produces a mixture of methane and carbon dioxide (60/40 mole ratio).

(5) The product gas is separated from CO_2, water vapour and traces of H_2S in a Benfield gas purification unit.

The kinetics of steps 1, 2 and 4 have been experimentally determined.

4.6.2.3 ECONOMIC ANALYSIS

A computer model of the process was constructed, into which experimental data were incorporated where available; in other cases, reasonable assumptions were made by analogy with other substrates.

A sensitivity analysis was carried out by calculating the product gas cost, with significant variables input over a range of values bracketing a "base-case". At the time of writing, many of the design parameters have not been optimised, let alone demonstrated on a pilot scale. Nevertheless, the model is useful for pinpointing the relative effects of process parameters on the cost of the SNG produced and indicating the most fruitful areas for future research.

The base-case was a projected biogasification facility, designed to produce 73.5 TJ/day (70 x 10^9 Btu/day) substitute natural gas from wet-harvested peat, processing over 7270 dry tonnes/day. The mass and energy balances are given in Table 4-21. Capital costs were based on literature values, updated to December, 1980. Finance charges were according to the public utility method as given in Section 4.5.2.4 (Peatgas). The base-case unit gas cost was C$6.80/GJ (C$7.14/10^6 Btu), the total capital requirement was C$291.7 million, and the net annual operating cost was C$138.6 million.

TABLE 4-21. BIOGASIFICATION BASE CASE MASS BALANCE.

	tonnes/day
Feed to Process	
Na_2CO_3	2182
Oxygen	2273
Ash	755
Peat (m.a.f. basis)	6836
Outputs from Process Step	
Dewatering	
Undissolved peat (m.a.f.)	684
Ash	27
Alkali	73
Digestion	
Fermentables	1518
Ash	728
Alkali	2200
Gas Purification	
Methane	1.88 × 10^6 m^3
CO_2	1.26 × 10^6 m^3
Power Requirement	193.8 MW
Net Energy Efficiency	33%

After: Ruoff *et al.* (1980)

The major contributors to the annual operating expenses are the costs of alkali and electricity (46% and 25%, respectively). About 79% of the unit gas cost is due to operating costs, so that the alkali contributes over 36% of the unit gas cost.

The assumptions forming the base case are given in Table 4-22 for the process conditions, Table 4-23 for the capital costs and Table 4-24 for the annual operating costs. A sensitivity analysis was carried out to show the effects of changing process and economic variables on the unit gas costs. The effects of some key variables are shown in Plate 4-18.

TABLE 4-22. BIOGASIFICATION BASE CASE DESIGN PROCESS ASSUMPTIONS.

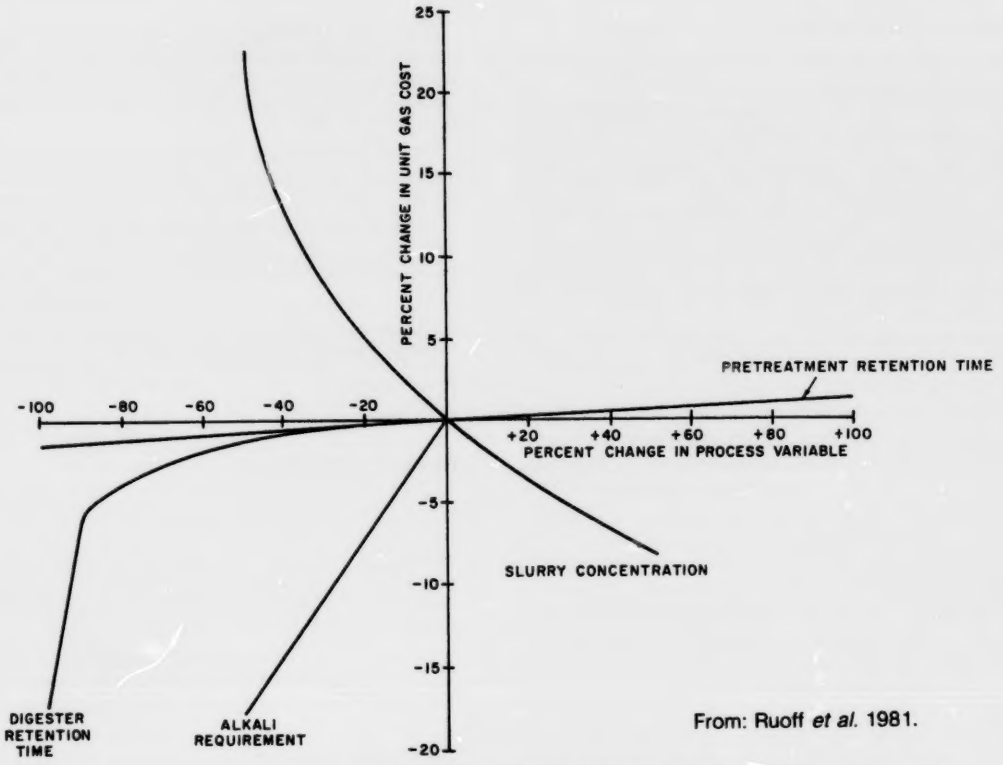
Process Step	Assumptions
Slurry Preparation	3% Solids Feed 8% Solids Output
Pretreatment-Solubilization	Plug Flow Reactor 90% conversion 0.3 kg Na_2CO_3/kg peat 150°C
Oxidation	Plug Flow Reactor 90% conversion 0.4 kg O_2/kg solubilized product converted 150°C 0.024 h retention
Heat Exchanger	10°C Inlet Slurry Temperature 37°C Exit Temperature for Feed to Digester
Liquid/Solids Separation	Undissolved Solids Separated to 25% Solids
Digestion	CSTR 37°C 20 day retention time 67% conversion of fermentable products Gas Composition, 60% CH_4/40% CO_2
Gas Purification	3% CO_2 Concentration in Purified Gas 6.83 MPa Output Pressure Power Requirement of 7.9 kW/m^3 SNG

From: Ruoff *et al.* (1980)

TABLE 4-23. BIOGASIFICATION BASE CASE CAPITAL COSTS.

Equipment	Costs US$
Slurry Preparation	100,000
Pretreatment—Solubilization	100,000
—Oxidation	1,300,000
Heat Exchanger	2,300,000
Liquid/Solids Separation	8,100,000
Digesters	97,000,000
Gas Purification	6,800,000
Pumps, piping, electrical, instrumentation	15,800,000
Total Equipment Costs	$131,500,000
Supporting Facilities	6,600,000
Total Capital Investment	$138,100,000
Contractor's Overhead & Profit	13,800,000
Engineering & Design	6,900,000
Subtotal Plant Investment	$158,800,000
Contingency	23,800,000
Total Plant Investment	$182,600,000
Interest During Construction	32,900,000
Start-up	23,000,000
Working Capital	3,600,000
Total Capital Requirements	US$242,100,000 C$291,700,000

From: Ruoff *et al.* (1980)



From: Ruoff *et al.* 1981.

PLATE 4-18. SENSITIVITY OF UNIT GAS COST TO PROCESS VARIABLES, BIOGASIFICATION OF PEAT.

TABLE 4-24. BIOGASIFICATION BASE CASE ANNUAL OPERATING COSTS.

Raw Materials	
Peat (US$3.30/tonne, dry)	US$ 9,100,000
Na_2CO_3 (US$66/tonne)	52,600,000
Utilities	
Electric (5¢/kWh)	28,100,000
Labor	
Operating (250 people, US$6/h)	3,100,000
Maintenance	4,000,000
Supervision	1,100,000
Administration and Overhead	4,900,000
Supplies	
Operating	900,000
Maintenance	4,000,000
Local Taxes and Insurance	7,200,000
Gross Operating Cost	US$115,000,000
	C$138,550,000

From: Ruoff *et al.* (1980)

The sensitivity of gas cost to peat cost was separately calculated to be about \$0.114/GJ (\$0.12/10^6 Btu) per \$1/dry tonne peat cost (base case C\$3.98/tonne). Therefore, the estimated Canadian wet-mined peat cost of \$18.70/dry tonne would add another \$1.68/GJ (\$1.77/10^6 Btu) to the unit gas cost.

It is apparent from the sensitivity analysis that the variables which have the greatest influence on the product cost are the delivered peat cost, the digester retention time and the alkali pretreatment chemical cost. The wet-mined peat cost is a very uncertain quantity at this time, and needs to be more closely estimated for Ontario conditions. The digester retention time has an excellent chance of being shortened from the 20 days taken for the base case to less than a day, by applying such novel techniques as thermophilic digestion or cell recycle in the digester. This development would reduce the unit gas cost to \$5.7/GJ (\$6.02/10^6 Btu). If 90% of the alkali could be recycled, the gas cost would be reduced to about \$4.23/GJ (\$4.46/10^6 Btu). A combination of both of these developments, if achieved, would provide SNG at \$3.32/GJ (\$3.50/10^6 Btu), assuming a wet-mined peat cost of \$3.98/dry tonne. Obtaining this is among the aims of the continuing research effort.

4.6.2.4 MASS AND ENERGY BALANCE

The values given in Table 4-21 for the mass and energy balance have only been partially confirmed in the laboratory. They serve as reasonable projections on which to base a preliminary economic evaluation. It is assumed that these are achievable through additional development work.

In particular, the rate of solubilized peat digestion will have to be increased fivefold to achieve 20 days fermentor residence time. This may be achieved through the removal of the suspected inhibition by sodium ions. The problem of effective alkali recovery would also be addressed concurrently. The solubilization and partial oxidation steps appear to have been adequately researched.

The base case described in the latest Dynatech report (Ruoff *et al.* 1981) projects an overall thermal efficiency of 33%.

4.6.2.5 ASSESSMENT

The bench-scale development of the process has been completed. Additional research funds have been obtained and further work is under way. This will concentrate on the continuous reactor development of the solubilization and partial oxidation steps and the bench scale investigation of an alternative process route: acidophilic fermentation,

followed by Hoffer-Mosst electrolysis to pentanol, an industrial solvent (Dr. D.L. Wise, personal communication).

It appears that Dynatech has found and developed a method for producing an anaerobic fermentation substrate from wet-harvested peat, and they are now exploring an alternative method of further biological processing. It is unlikely that a process will be demonstrated before the mid-eighties.

This research work is significant, as it aims at processing wet-mined peat directly without dewatering, and further research will likely be able to utilize developments from the very active field of biotechnology.

4.6.3 THE VYRMETHANE PROCESS

4.6.3.1 GENERAL

Utilizing the native methanogenic microflora of the peat-bog itself and separating methane from continuously recirculating bog water is the idea behind this approach to utilizing peat. As proposed, it would result in the least disturbance of the peatlands.

4.6.3.2 CURRENT STATE OF DEVELOPMENT

The Swedish Board for Energy Development has sponsored pilot plant operations since 1978 by Vyrmetoder AB of Taby, Sweden. The anticipated production rates quoted in this report are based on this work.

In the spring of 1982, a demonstration facility will be started up, producing 8-900 kW in the form of low-pressure methane gas from 50 hectares of peatland. The process is patented (Martinell, 1981), but not yet commercially available. Two sizes of production modules are anticipated: 100 and 700 litre/sec bog water pumping and degassing capacity, which should produce 65 kW and 455 kW net chemical energy respectively.

4.6.3.3 PROCESS DESCRIPTION

The unique feature of the process is that the peat is left undisturbed in the bog; the bog water is collected in shallow wells, pumped to a central degassing station, where the dissolved methane is removed by vacuum and the spent water is returned to a parallel row of recharging shafts. There is a hydraulic gradient between points of withdrawal and return and the water percolates through the bog dissolving biologically generated methane and carbon dioxide on the way.

The productivity of the bog depends on the permeability of the deposit. and the kinetics of methanogenesis within it. It is understood that a minimum permeability of 10^{-5} m/sec is required to achieve 100 ℓ/sec pumping rate at 7.5 m distance between suction and recharge. This requirement eliminates clayey and silted bogs and those with average humification above H5. Assuming further that one third of the moisture in the bog is mobile, 25 hectares of 1 metre thick bog is required for 100 ℓ/sec pumping rate.

It is anticipated that 20 mg of methane gas can be collected per litre of water circulated, or 172 kg methane/day. This depends on the biological kinetics, which, in turn, is temperature dependent. The demonstration aims to show that such a production rate can be sustained in regions where the annual mean temperature is 6°C or above.

The production module consists of supply and recirculation pipes, pump, vacuum degassing unit and a gas engine-driven generator to supply the electrical needs of the process.

4.6.3.4 MASS AND ENERGY BALANCE

Anticipated production: 20 mg/ℓ methane gas, at 100 ℓ/sec. At 50 MJ/kg methane, this is equivalent to 100kW gross calorific value. Pumping and degassing is said to consume 7 mg/ℓ methane, or 35 kW, at 40% electrical conversion and 60% pump efficiency.

The net chemical energy yield is 65 kW or 111.8 kg/day methane, mixed with carbon dioxide and water vapour.

4.6.3.5 CAPITAL AND OPERATING COST ESTIMATE

The estimated production cost is shown in Table 4-25. The plant will be designed to operate with minimum supervision.

TABLE 4-25. VYRMETHANE IN-SITU BIOGASIFICATION PROCESS.

Costs (1981) Based on data provided by Vyrmetoder AB	
Capital Investment	$37,000
Maintenance and Operation	2,400
Capital Charges: 10 yr, 20% CRF	8,825
Total Operating Cost:	$11,225
Annual production, @ 97.5% service factor, average 13 mg CH_4/ℓ, 100 ℓ/sec pumping	40,000 kg
Production costs:	$0.281/kg CH_4
	$5.67/MBtu
	$5.40/GH
Not including royalties for process or peatland.	

4.6.3.6 ENVIRONMENTAL CONSIDERATIONS

It is evident that this process will operate with minimum disturbance to the environment. Over the years of operation, as the peat is gasified, the volume of the bog will slowly shrink, but without the surface vegetation being disrupted.

4.6.3.7 ASSESSMENT

The problems which remain to be solved over the demonstration period are:

- determine the biological kinetics for methanogenesis in the bog
- assess the effects of nutrients added to the returned water stream
- demonstrate that 20 mg/ℓ methane can be recovered continuously, over several years
- demonstrate the continuous operation of the gas engine on marsh-gas.

4.6.4 BIOTHERMGAS™

This process, under development at IGT (Chynoweth *et al.* 1980), combines biological and thermal methods for the total conversion of organic feeds (biomass, wet-mined peat) to methane. Although the experimental and economic evaluations published to date refer to biomass feedstock, the process is thought to be applicable to wet-mined peat, and work is being done to adapt it. The results of experiments with peat will be presented at the IGT Peat Symposium, in December, 1981.

As previously described, anaerobic fermentation of peat is carried out at 85-92% moisture content, allowing the utilization of wet-mined bog material under mild process conditions. However, without solubilization of the solids, less than 50% of the organic material is digestible, and peat lacks sufficient nitrogen and phosphorus for efficient fermentation (typically C/N <15, C/P < 75 required).

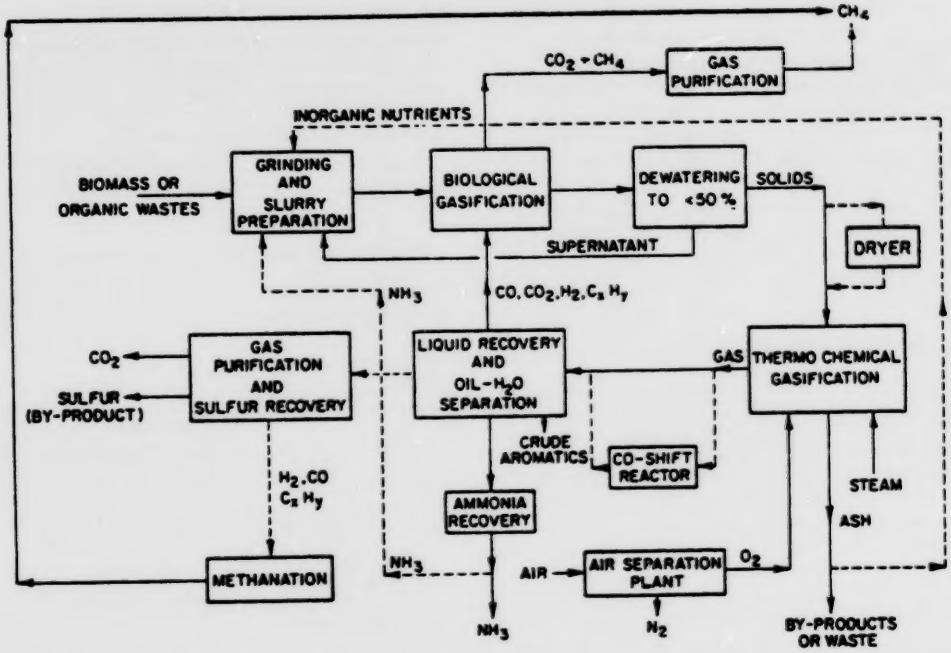


PLATE 4-19. BIOTHERMGAS PROCESS SCHEME.

To get around these problems, yet allow the utilization of wet feedstock, a novel approach is proposed in the BIOTHERMGAS™ process. By analogy with the anaerobic digestion of sewage sludge, it is anticipated that the digested organic solids may be mechanically dewaterable to 50% moisture or less. If this proves to be the case, the digested and dewatered residues could be thermally gasified to yield a mixture of CO, CO_2, H_2, NH_3 and hydrocarbons. The nitrogen and phosphorus compounds would be recovered and returned to the digester, saving the cost of added nutrients beyond an initial dose.

There are two alternative routes for the processing of thermally generated gases: (a) conventional purification followed by catalytic methanation to yield pipeline quality SNG, which is added to the purified, biologically produced methane and discharged as the main product; or (b) the gases may be led back into the anaerobic digester to provide agitation and heat to the digester and to serve as substrates for the biomethanation reactions. This approach obviates the need for a separate catalytic methanation step. Both flowsheet alternatives are shown in Plate 4-19.

Biomethanation of gases from the gasification of coal by mixed methanogenic cultures has been demonstrated by Daniels and Zeikus (1977) and Wise *et al.* (1978). It proceeds according to the following reactions, performed by methanogenic bacteria:

$$CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$$
$$CO + 3\ H_2 \rightarrow CH_4 + H_2O$$
$$4\ CO + 2\ H_2O \rightarrow CH_4 + 3\ CO_2$$

Direct recycle of the raw synthesis gas eliminates the costly and inefficient steps of water purification and gas upgrading normally associated with thermal gasification. This recycle also retains ammonia nutrient within the system. Phosphorus can be recovered from the gasifier ash and recycled to the digester.

The biological gasification (digestor) can be operated in the mesophilic (~35°C) or thermophilic (~55°C) temperature range. Although mesophilic operation has been the usual practice for industrial scale anaerobic digestions, if there is sufficient waste heat available to warm the digester (as in this case) thermophilic operation permits higher digester loading and better dewaterability of residues.

A study of three process options (Table 4-26) was carried out to estimate the materials and energy balance for BIOTHERMGAS, using estimated performance and cost parameters where experimental data were not available (Chynoweth *et al.* 1980). The study compared the estimated economics of catalytic methanation, mesophilic and thermophilic biomethanation, as part of the complete BIOTHERMGAS process. Bermuda grass was used as the substrate in the systems analysis; other biomass options (grasses, trees and aquatic plants), sewage sludge, municipal solid waste and wet-harvested peat are also being evaluated in the current experimental program.

TABLE 4-26. BIOTHERMGAS™ SYSTEMS ANALYSIS STUDIES.

	Example 1	Example 2	Example 3
Feed	Bermuda Grass	Bermuda Grass	Bermuda Grass
Loading, dry tonnes/day	9080	9080	9080
Digestion	Mesophilic	Mesophilic	Thermophilic
Gasifier	Two-stage, O_2-Steam	Two-stage, O_2-Steam	Single stage, O_2-Steam
Methanation of Thermal product gases	Catalytic	Biomethanation	Biomethanation
SNG output			
TJ/day	127.3	117	122.9
tonnes/day	2346	2156	2246
Cold gas efficiency, %*	74	68	72
Total plant efficiency, %	82	76	80

*Cold gas efficiency defined as the product gas energy divided by the feed energy
From: Strivastava *et al.* (1981)

The mass, energy and economic balances are presented in Tables 4-28 to 4-32. Table 4-27 gives the chemical composition of Bermuda grass. Table 4-26 gives an overall outline of the systems analysis studies and estimated plant efficiencies. Tables 4-28 and 4-29 show the operating parameters assumed for the systems analysis. Tables 4-30 to 4-32 provide details of the economic analysis.

TABLE 4-27. PHYSICAL AND CHEMICAL CHARACTERISTICS OF BERMUDA GRASS

Total Moisture, % total wt	33.0
Total Solids, % total wt	67.0
Volatile Solids, % dry wt	95.0
Ash, % dry wt	5.0
Heating Value, Btu/lb dry	8180
Total Carbon, % dry wt	47.1
Total Hydrogen, % dry wt	6.04
Total Oxygen, % dry wt	39.6
Total Nitrogen, % dry wt	1.96
Total Sulfur, % dry wt	0.21

From: Chynoweth *et al.* (1980)

TABLE 4-28. OPERATING PARAMETERS FOR GASIFICATION OF BERMUDA GRASS UTILIZING THE BIOTHERMGAS PROCESS (EXAMPLES 1 & 2).

A. Anaerobic Digestion	
Temperature	35°C (95°F)
Culture Volume	126.7 × 10^6 cu ft
Loading	0.15 lb VS/cu ft-day
Retention Time	12 days
Assumed Methane Yield	3.50 SCF/lb VS added-day
Methane Content in Digester Gas	60 mol %
B. Thermal Gasification (Steam-Oxygen)	
Two-Stage Reactor:	
Stage One	
Temperature	1475°F
Pressure	530 psig
Solids Residence Time	1-5 sec
Stage Two	
Temperature	1700°F
Pressure	545 psig
Solids Residence Time	10 min
C. Chemical Methanation	
Temperature	830°F
Pressure	410 psig
Methane Content	94 mol %

From: Srivastava *et al.* (1981)

TABLE 4-29. OPERATING PARAMETERS FOR GASIFICATION OF BERMUDA GRASS UTILIZING THE BIOTHERMGAS PROCESS (EXAMPLE 3).

A. Anaerobic Digestion	
Temperature	55°C (131°F)
Culture Volume	25.3 × 10^6 cu ft
Loading	0.75 lbs VS/cu ft-day
Retention Time	7 days
Assumed Methane Yield	4.0 SCF/lbs VS added
Methane Content in Digester Gas	60 mol %
B. Thermochemical Gasification (steam-oxygen)	
Single-stage Reactor	
Temperature	1800°F
Reactor Pressure	50 psia
Carbon Conversion	99%
Solids Residence Time	10-20 min

From: Srivastava *et al.* (1981)

TABLE 4-30. ECONOMIC ANALYSIS ASSUMPTIONS.

Discounted Cash Flow Analysis	
1980 Constant Dollars	
Cost of Debt (%)	12
Cost of Equity (pretax basis, %)	15
Debt/Equity Ratio	75/25
Construction Period (years)	2
Interest Rate During Construction (%)	15
Plant Life (years)	20
Tax Rate (%)	50
Investment Tax Credit (%)	10
Straight Line Depreciation	
Scaling for Digesters and Ancillaries	1:1 ratio
Scaling for Gasifier and other Equipment	0.7 exponential factor

From: Srivastava *et al.* (1981)

TABLE 4-31. BIOTHERMGAS PLANT PRELIMINARY CAPITAL COSTS.

	Capital Cost (US$10^6)	
Cost Item	**10,000 TPD (0.75 loading) Examples 1 & 2**	**10,000 TPD (0.75 loading) Example 3**
Feed Preparation	40	40
Digesters	456	91
Dewatering	38	38
Gasifier	50	50
Heat Exchangers	10	10
Liquid recovery	10	10
Gas Purification	45	45
Oxygen Plant	30	30
Start-Up, Contingencies @ 30%	204	94
Totals, US$	883	408
Totals, C$	1064	492

From: Srivastava *et al.* (1981)

TABLE 4-32. BIOTHERMGAS PRELIMINARY PRODUCTION ECONOMICS*.

	Plant Capacity	
Cost Item	**10,000 TPD Examples 1 & 2**	**10,000 TPD Example 3**
Total Plant Cost ($10^6)	883	408
Feedstock @ $30/ton ($10^6/yr)	84	84
Labor and Maintenance @ 5% ($10^6/yr)	44	24
Gas Production (10^{12} Btu/yr)	36.4	36.4
Levelized Cost of Service ($/$10^6$ Btu)	7.60	4.80
C$/$10^6$ Btu	9.16	5.78
C$/GJ	8.68	5.48

*US dollars, unless otherwise noted
From: Srivastava *et al.* (1981)

Based on the preliminary economic analysis of the three examples, IGT drew the following conclusions (Srivastava *et al.* 1981):

- thermophilic digestion in the BIOTHERMGAS process would result in significantly lower product costs in commercial operation than equivalently sized facilities using mesophilic digestion. This conclusion should apply as well to digestion alone, without thermal gasification of the digester effluent cake.

- a smaller plant using thermophilic digestion (example 3) can be more economical than a larger plant using mesophilic digestion (examples 1 and 2).
- the BIOTHERMGAS process has potential for methane production at a relatively low cost if compared to other methane production alternatives analysed on the same economic basis.

Experimental work to prove the BIOTHERMGAS process has been carried on at IGT, using in-house funds to date. External support is being sought now. The key concept of biomethanation of thermochemical product gases has been proven (Chynoweth, 1980; Srivastava *et al.* 1981). Additional laboratory work is proceeding on the effect of digestion on the dewaterability of biomass and peat; co-digestion of wet peat with biomass; and thermophilic digestion of substrates. It is estimated that about 2 years of laboratory investigation is required before PDU-scale demonstration (D.P. Chynoweth, personal communication). The process may be commercially available in the mid-eighties.

4.7 DIRECT COMBUSTION PROCESSES

4.7.1 GENERAL

The direct combustion of milled and sod peat as solid fuel in commercial furnaces dates back over 30 years in Germany, Russia, and Ireland. Sod peat is fired in sloping grate or chain grate furnaces, common in Ireland, up to a maximum size of about 150,000 pounds of steam per hour. Milled peat is fired in suspension as a pulverized fuel in commercial boilers, up to 600,000 pounds per hour capacity in Finland and in boilers about 3 times this size in Russia.

The differences in design between peat fired boilers and other solid fuel (coal) boilers are not great. However, the design and operating elements which are distinct to peat firing are included herein.

4.7.2 COMMERCIAL TECHNOLOGY

4.7.2.1 BOILER PLANT SYSTEMS

The boiler plant systems most affected by milled peat firing are: materials handling, fuel pulverization, and fuel combustion. Sod peat fired plants do not have the same materials handling problems as those burning milled peat, for the risk of spontaneous combustion is much less. Furthermore, sod peat need not be pulverized, as it is fed in lump form to the boiler grate. Sod peat fired boilers tend to have fouling problems because the combustion rate is slow and the "as fired" moisture content is higher than that for milled peat. The balance of the boiler plant equipment is similar to that of any other conventional solid fuel plant and is not affected by the use of peat as a fuel.

4.7.2.2 MATERIALS HANDLING SYSTEMS

The sod peat handling systems are essentially the same as wood chip and bark handling systems currently used in Ontario pulp and paper plants, and, apart from material size differences, no major design changes are necessary.

Milled peat-fired plants have specially designed materials handling systems. As milled peat is low bulk density material and is prone to spontaneous combustion, in-plant fuel storage is kept to a maximum of 3 to 4 days' supply and bulk fuel storage is maintained at bog side. Effective peat transportation systems thus become an absolute necessity.

Upon arrival at the receiving station by side dumping haul trucks or rail wagons, the peat is dumped into a hopper with a grizzly which removes frozen lumps and roots. Dual conveying systems to the live in-plant blending and storage bunker are enclosed and have an electro-magnet for removing tramp iron. The peat blending and storage bunkers have up to 3 to 4 days' storage capacity and are constructed of reinforced concrete. The peat is fed through overhead conveyor galleries which distribute the peat evenly throughout the length of the bunker. The bunker foundation incorporates a travelling screw conveyor by which the peat is transferred to 2 enclosed belt feeders which go to the bunkers at the top of the boiler house. The peat is then fed from the overhead bunkers to the pulverizing mill by pan feeders which can be regulated to control the steam output of the boiler. Hot flue gases then join the peat and reduce its moisture content to about 20% and the peat is then injected into the boiler for firing.

4.7.2.3 FUEL PULVERIZING

Sod peat fed to a grate fired boiler does not require pulverizing and can be fed directly to the furnace at 30% moisture. Milled peat requires pulverizing to almost a powder and additional drying to lower the moisture from about 50% as received to about 20% as fired.

This is achieved by feeding the milled peat to a "HOT GAS SUCTION PULVERIZING MILL". The mill has rotating beaters or hammers which, through impact, pulverize the peat into smaller particles.

Hot furnace gas ducted from the top of the boiler also enters the mill and dries the particles of peat as they are being pulverized. As well, the furnace hot gas entrains the pulverized particles of peat in a high velocity gas stream and carries these particles through the fuel classifier (where oversized particles are rejected and recycled) and into the burner.

The peat/gas mixture at the point of firing is automatically controlled in order to maintain the desired furnace combustion rate and to overcome fluctuations in fuel quality.

4.7.2.4 FUEL COMBUSTION

Sod peat furnaces receive the solid lump fuel at approximately 30% moisture content. As discussed previously, fuel preparation such as pulverizing, and entrained air burner feed are not necessary for firing a grate furnace; thus, sod peat feed systems and fuel combustion are very simple. The most important features in sod peat combustion, whether a sloping grate or chain grate type, are fuel pre-drying between the burner and the grate to control the moisture content and radiant fuel heating in advance of the furnace entry port to control the fuel bed height, and preheated secondary air supply to create turbulence and control flame profiles.

Milled peat furnaces require injector burners to feed the air entrained particles and blend in combustion air to produce consistent flame characteristics. In Ireland, slot type burners are used and, in Finland, generally whirl burners are applied.

In the slot type ejector burners, the milled (pulverized) peat is blown through refractory slot openings in the furnace walls in a tangential configuration of 4 burners, of which 3 are normally in operation, and one is on standby. Primary air is forced into the furnace on either side horizontally to the fuel slots, and secondary air comes in through openings vertically above and below the bank of burner slots. Auxiliary fuel oil burners are suitably located on the furnace walls.

In the whirl burners used in Finland, peat and preheated primary air are blown usually through the inner circle of the burner; secondary air enters the furnace around the outer circle of the burner. The auxiliary fuel oil burner is located in the centre of the whirl burner. In Finland both vertical and horizontal cyclone firing systems are used.

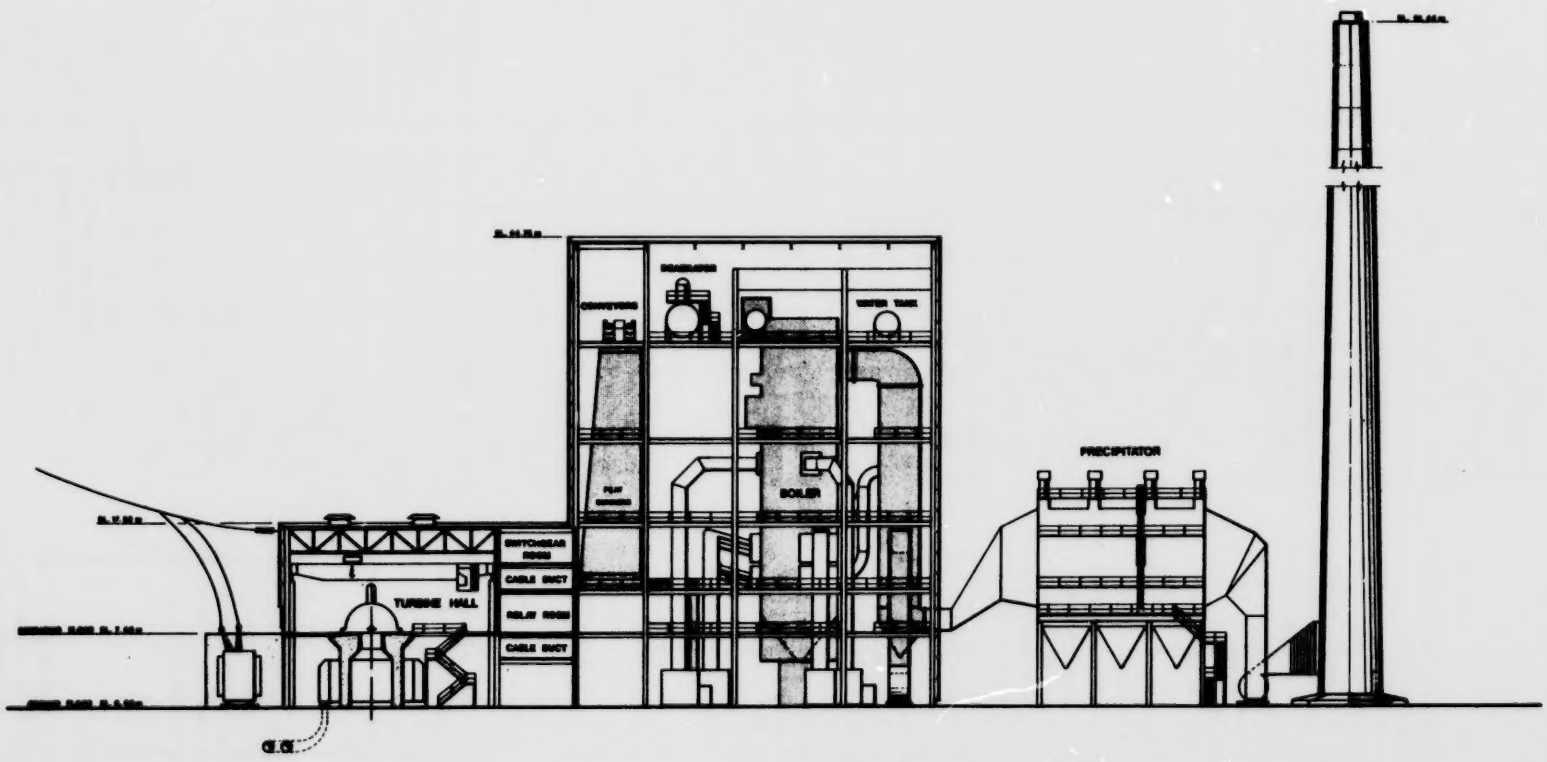


PLATE 4-20. SECTION THROUGH 1 x 40 MW PEAT-FIRED POWER PLANT.

A difference between installations commonly used in the two countries can be observed in the use of oil as auxiliary fuel: the Irish use auxiliary oil firing only for starting, low load and stabilizing operations, whereas the Finns use oil firing almost continuously along with peat to the extent of about 15 per cent of the fuel.

4.7.2.5 COSTS

Direct combustion process costs are available from Ireland and Finland for both sod peat and milled peat fired furnaces. However, as thermal efficiencies vary considerably with boiler size, fuel type and firing systems, to apply these costs in Ontario without being site and size specific would not be meaningful. As well, feed stock costs will also vary from one climatic region to another. In order to determine what the direct combustion process costs might be for a Canadian built plant, the Federal Government of Canada (EMR) commissioned a detailed feasibility study of the cost of power from a 40 MW peat-fired thermal electric power station. The results of this work were presented at the 6th International Peat Congress during August, 1980, in a joint paper by the Federal Department of Energy, Mines and Resources, and Montreal Engineering Company, Limited.

The study was conducted with specific reference to a Northeast New Brunswick station location and peat supply. As discussed in Part 3 of this study, the cost of producing peat in south-central Ontario is estimated to be similar to that in Northeast New Brunswick, and similar peat requirements apply. Direct combustion costs estimated for the New Brunswick situation are expected to be applicable to Ontario, allowing for inflation of capital and operating costs.

The findings of the New Brunswick Peat Study were that the levelized cost of power (in 1978 dollars) from a 40 MW single unit power station would be 54.8 mills/net kWh compared with 42.0 mills and 61.7 mills, respectively, for similarly sized coal and oil-fired plants, where prices of coal and residual oil were assumed as being $46.30/tonne and $25/barrel, respectively, delivered to the station. A cross-sectional view of the 40 MW station is included on Plate 4-20.

Oil was left out of further consideration. The computed cost of power from coal (42.0 mills/net kWh) did not include the cost of abating the effects of the high sulphur and high ash contents of New Brunswick coal. It is roughly estimated that, when these costs are added, then the figure of 42 mills may rise to about 46 mills or even 48 mills/net kWh, which would place it close to the cost of power from peat (54.8 mills/kWh).

The New Brunswick feasibility study included a comparative financial analysis to indicate in nominal dollars the revenue required per kWh to recover costs, and obtain a return on investment at a nominal 14% per annum. The results showed that the rankings of the 3 alternative fuels over a 30 year plant life would depend upon the price increase assumptions made.

It is worth noting that the comparisions are all based upon 40 MW single unit stations, which is not the most realistic situation, particularly with respect to coal (oil being left out of consideration). Economies of scale would undoubtedly favour coal-fired stations which have much larger units than are the present proven standards for peat firing in western countries.

4.7.3 EXPERIMENTAL PROCESSES

The Pyroflow Combustor and Outokumpu Combustion Plant are two experimental fluidized bed combustion processes and both processes are at the demonstration stage. The process equipment replaces the standard direct combustion furnace and increases the overall thermal efficiency while providing easier fuel combustion control.

4.7.3.1 PYROFLOW COMBUSTOR

It has been reported by the Hans Ahlstrom Laboratory and General Atomic Company that the fluidized bed systems will provide the most advanced method of combusting multiple fuels, while potentially meeting the most rigid SO_2 and NO_x environmental emission standards. The Pyroflow combustor uses the circulating fluidized bed technique for recovering energy from peat and wood wastes. Combustion takes place between 700° and 1000°C. Due to the efficient mixing of the circulated material, the combustion is stable in spite of the variations in particle size, moisture content, and calorific value of different fuels.

A demonstration plant has been on stream since January, 1979, at a fiberboard mill in Pihlava, Finland. The Pyroflow combustor is retrofitted to an existing bark boiler having the combustion capacity of 2 kg/s of peat, corresponding to a net heat output of 12 MW (i.e. 5.7 kg/s of steam at 85 bar and 520°C).

The Pyroflow boiler at Pihlava was commissioned in mid-January, 1979, and, after a two-month test run by Hans Ahlstrom Laboratory, it was turned over to the plant operators. Since that time, the plant has been operating without any forced outages due to equipment or operating errors. The retrofit of the Pyroflow reactor has not increased the original plant operating crew.

Total fuel cost for 1979, using mainly peat and wood refuse, was $\$2.44/10^6$ Btu output; $\$0.13/10^6$ Btu output was for oil for commissioning and startup. This compares with $\$5.85/10^6$ Btu output heat cost for fuel oil operation on fuel oil alone. It has been reported that these figures were calculated from the plant financial records.

Capital costs for retrofitting the Pyroflow reactor to the existing bark boiler at Pihlava was $1.0 million in 1978 dollars. The investment included the combustion unit with auxiliary equipment (i.e. belt conveyor, disc screen feed hopper with feeding system, primary and secondary air fans, instruments, electric installation, and modification of the forced circulation system of the La Mont boiler).

Burning peat (2/3) and wood waste (1/3) saves $770,000 annually versus burning oil, based on a 7500-hr annual operation time. Power and maintenance costs are $50,000 more than oil burning. Labour costs have not increased because the same staff that operated the La Mont boiler is now also operating the Pyroflow boiler. The economy of retrofitting the Pyroflow boiler to the existing bark boiler at Pihlava is reported to be excellent, with the payback time for the installation being a little over one year.

4.7.3.2 OUTOKUMPU FLUIDIZED BED COMBUSTION PLANT

The Outokumpu fluidized bed combustion plant is well described in descriptive literature from Outokumpu which presents the following summary of the process.

"Outokumpu has adopted a fluidized bed process for combustion of low-calorific fuels and the experiences gained have been positive. This method has been operated at the Outokumpu Kokkola works since 1977 mainly for the combustion of milled peat but alternative fuels, e.g. sod peat, coal, wood chips, bark and sawdust have also been used in this plant.

Fuels are burnt in the fluidized bed where a bed of sand is used. Fuel is fed into the bed by a pneumatic feeder, which prevents gas from flowing out of the boiler, through a feed pipe. Combustion gases flow from the bed into the boiler and further through the economiser into the electrostatic precipitator.

In the fluidized bed combustion the maximum allowable gas velocity in the bed, the amounts of primary and secondary air and the amount of heat removed from the bed primarily depend on the grain size, heat value and moisture content of the fuel.

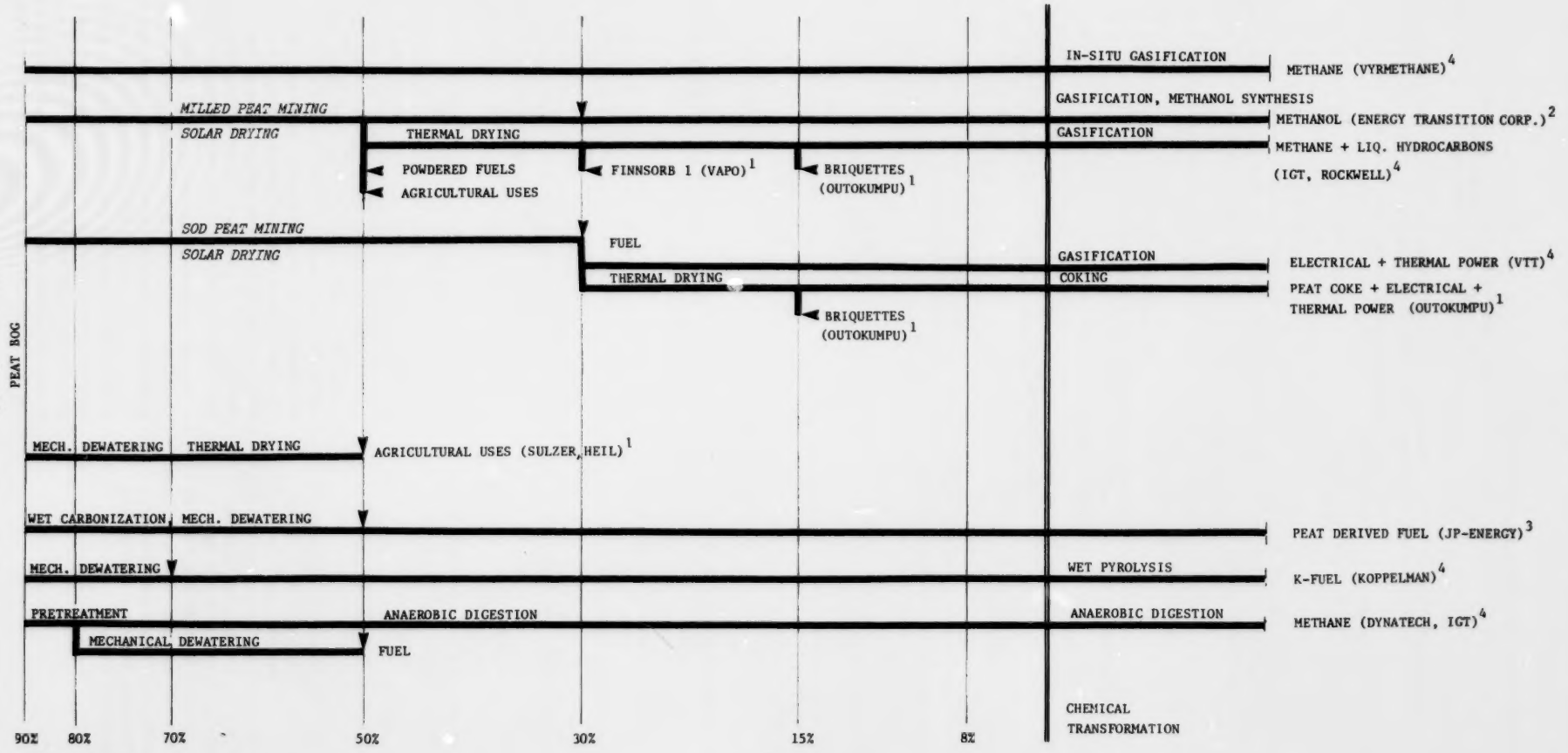


PLATE 4-21. PEAT PROCESS TECHNOLOGY.

Legend:
1. Plants in Operation.
2. Designing First Plant.
3. Feasibility-Study Stage.
4. Under Development.

TABLE 4-33. AVAILABILITY OF PEAT PROCESSING TECHNOLOGY.

Technology	Product(s)	Source	Maturity of Technology in 1981	1982	1983	Accuracy of Capital Estimate
Mechanical dewatering	~ 70% MC peat	Sulzer, Ingersoll-Rand	1			A
Thermal drying	Horticultural or fuel peat	Many sources	1			A
Drying and briquetting	Briquettes, ~ 15% MC	Outokumpu	1			B
Coke production	Metallurgical coke, BBQ fuel, feed for act. carbon	Outokumpu	1			B
		Karl Still	1			Available later
Heat treatment	Oil absorber	VAPO	1			Available later
Activation	Activated carbon	Karl Still	1			Available later
Boiler plant systems	Electrical and thermal energy					
—Injector burners		Many sources	1			B
—Pyroflow™ Combustor		Ahlstrom	1			B
—Fluidized bed combustion plant		Outokumpu	1			B
Wet carbonization	"PDF" solid fuel	JP-Energy/Wheelabrator	3	2		B
Wet pyrolysis	"K-Fuel" solid fuel	Koppelman/SRI	4	4	4	N/A
Wet combustion	Energy	Ontario Research Foundation	5	5	4	N/A
PEATGAS™	SNG or syngas or MBG	IGT	4	4	3?	C
CS/R Hydrogasification	SNG, benzene	Rockwell Int'l	4	4	4	C
Koppers-Totzek Syngas	Methanol	Peat Methanol Assoc.	2	2,3	2,3	A
MINO Syngas	Methanol	Studsvik, RIT		4	4	N/A
1 MW sod gasifier	Electrical & thermal energy	VTT	4	4,3	2	C
25 MW sod gasifier	Low-Btu gas	VTT	4	4		N/A
Direct liquefaction	Bitumen	Sherbrooke U	5	4	4	N/A
		RIT	5	4	4	N/A
Biogasification	SNG, pentanol	Dynatech	5	5	5	C
BIOTHERMGAS™	SNG	IGT	5	5	5	C
Vyrmethane	SNG	Vyrmetoder	5	4	4	C

State of development: 1. Operating plant(s)
2. First commercial plant in design
3. Ready for licencing
4. Development/Demo unit
5. Bench-scale, research unit

Accuracy of capital estimates: A Commercial venture reliability
B Detailed estimate
C Factored estimate
N/A Not available

In the fluidized bed combustion of milled peat it is not necessary to remove heat from the bed because the temperatures in the bed can be kept within the desired limits by regulating the amounts of primary and secondary air.

Advantages of fluidized bed combustion are:

- A high efficiency of combustion, over 99%
- Fuels with moisture fluctuations and of different type can be burnt in the same unit
- No predrying and milling of fuel is required
- There are no moveable parts in the furnace
- Combustion temperatures can be controlled within the desired limits and thus avoid troubles caused by the melting of ash
- No supporting fuel is needed
- Environmental pollution is low compared with other combustion methods."

Discussions with Outokumpu engineers, during a recent trip to Finland, included a review of the estimated capital costs of 25 MW and 50 MW fluidized bed peat fired plants for North America. It was estimated by Outokumpu that the North American delivered plant including boiler, material handling systems, gas cleaning, and stack would be $5,000,000 for a 25 MW plant and $8-9,000,000 for a 50 MW plant ($U.S., 1981). This cost estimate does not include civil works such as foundations, site preparation and plant services, and buildings or closures. Design to start-up time was further estimated to be about 2 years.

4.8 SUMMARY OF PEAT PROCESSING TECHNOLOGY

Peat dewatering and processing technology is undergoing intensive development in the U.S.A., Finland, Sweden and Canada. At the present time, only small tonnages of peat are consumed outside the traditional applications for direct combustion and agriculture. A few alternative processes are available commercially at the present time, and several more will come on the market in the next five years. Table 4-33 shows the schedule for peat technology development as forecast by those engaged in the work and the indicated accuracy of their capital cost estimates.

Products are obtained from peat by combining the following operations in certain ways: harvesting, which delivers to the process either wet bog material or solar-dried solids; pretreatment, consisting of mechanical pressing, wet carbonization and thermal drying either singly or in combination; and processing, in the course of which a variety of treatments yield useful products. When building a process-train leading to a desired product, the output of one operation must match the input specifications of the next. These are described in the report. To visualize the major processing routes encountered in the study, consult Plate 4-21.

In order to eliminate limitations due to climatic, environmental and production-scale factors, wet harvesting methods have been proposed, which deliver bog material to the processing plant at 80-97% moisture content. The technologies processing wet mined peat are distinct from those utilizing solar-dried material. Several of these are in an early stage of commercialization (see below). However, wet mining technology has not received sufficient attention, and the economics of it are not known with any confidence.

Two experimental processes, under development at IGT and Dynatech R & D Corporation, employ anaerobic digestion of wet mined peat slurries to produce substitute natural gas (SNG).

Machinery is now available for mechanically dewatering moss peat (I-R roller press) and/or fuel peat (Sulzer belt press) to 70% moisture on a moderate scale of production (50-100 tonne/day dry solids per unit). Thermal dryers will further reduce the moisture content to 50% or lower.

For large scale production (minimum 200,000 tonne/yr), the JP-Energy/Wheelabrator-Frye wet carbonization process yields from wet mined peat a uniform, pelleted or powdered solid fuel at 8% moisture. Its cost was estimated to be $3.67/MJ based on uncertain harvesting costs. The application being promoted for this product is substitution for residual oil in industrial boilers or other direct combustion applications.

Considering the potential savings of petroleum-based fuels which could be realized if the JP-Energy process and product live up to expectations, IT IS RECOMMENDED that the demonstration of this technology be followed with close attention, the market and applications of the product be investigated in greater detail and wet harvesting methods and costs for a site-specific Ontario application be worked out in the next phase of this study.

The production of substitute natural gas from milled peat is being studied in experimental units at IGT (PEATGAS) and Rockwell International (CS/R Hydrogasification). The former yields predominantly methane, but can be designed for synthesis gas production. The latter, operating at high hydrogen partial pressures, allows the optional co-production of benzene, along with the methane. Factored estimates for plant design were carried out for both processes to evaluate capital and operating costs and revenue requirements for 250 $\times$ 10^9 Btu/day installations. Neither process is expected to produce SNG at the price at which it is currently available in Ontario.

However, considering that the price of natural gas in Ontario is following an upward trend, and that both large scale milled peat harvesting technology and the PEATGAS process are in a state of rapid development, IT IS RECOMMENDED that, in the next phase of this study, the feasibility of large scale SNG production via the PEATGAS technology be evaluated at a selected site in Ontario.

The composition and chemical reactivity of peat is similar to cellulosic biomass. This is recognised by several groups active in process development which are experimenting concurrently with biomass as well as peat feedstock. These processes are: BIOTHERMGAS (IGT), MINO (Studsvik-RIT), and VTT gasifiers.

It is important to be aware of these similarities in order to take advantage of potential synergism in future research expenditures.

Synthesis gas may be produced from peat by adapting coal gasification technology (Koppers-Totzek) or taking a fresh approach (Studsvik). Syngas may then be converted to methanol by well established technology.

In the United States, a 614 tonne/day methanol plant, using Koppers-Totzek gasification of milled peat, is being designed for 1984 startup. The low cost milled peat to be produced at First Colony Farms in North Carolina will allow the production of methanol for U.S. $0.75/gallon (1981) with adequate return on investment (Peat Methanol Associates).

Optimization of the entire peat-to-methanol process-train led to the design of the 300 kg/hr MINO process development unit, scheduled for startup in late 1982 (Studsvik, RIT, Sweden).

Considering methanol's rapidly increasing potential as an automotive fuel, the developing state of peat-to-methanol technology, as well as improvements in large scale milled peat harvesting technology, IT IS RECOMMENDED that, in the next phase of this study, the following process routes be evaluated with conditions specific for an Ontario location:

- Koppers-Totzek gasification
- PEATGAS process, in the synthesis gas configuration
- Studsvik MINO gasification process

all of them coupled with a conventional methanol synthesis plant.

Peat can be carbonized by commercially available technology (Outokumpu) to form two products: coke for metallurgical purposes, or a partially carbonized char which serves as starting material for activated carbon.

Both of these products are known and used in Europe. The secretive nature of the activated carbon manufacturing industry would require close co-operation with one or more manufacturers before the potential of Ontario peat can be assessed in this application. The application of peat-coke in existing metallurgical processes would also merit further study, since interest in this product has been reported from export markets, e.g. Japan, Norway, Germany.

Therefore, IT IS RECOMMENDED that the process and market economics of peat carbonization products be studied in greater detail than was possible within the terms of reference of this project.

The direct combustion of peat in thermal and electrical energy production relies on well established technology which is applied in the USSR, Ireland and Finland. The scale of possible application ranges from household use through industrial boilers and district heating to power stations.

Industrial boiler plant systems burn sod peat in grate furnaces; milled peat is fired in suspension as a pulverized fuel. Fluidized bed combustion systems have recently been made available commercially by Ahlström and Outokumpu companies.

PART 5
Potential Applications of Peat in Ontario

5.1 INTRODUCTION

This Part identifies and discusses several strategies that could be pursued in Ontario to develop the peat resources of the province in an effective way. The analyses are very general and, as such, only indicate which alternatives are felt to offer the greatest potential.

In Section 5.2 the current uses of peat and those under development are listed and some are briefly discussed. Based on this list and material presented elsewhere in this report, several potential applications are identified. Those applications thought to be reasonable possibilities, based on both the consultant's experience in peat and other natural resource industries and a technical and cost perspective, were selected for consideration in this study.

The selection process leading to the eight alternatives to be investigated was based on limited data and therefore may have omitted alternatives in early stages of development. Technical and cost criteria used in the selection were:

1) the characteristics of the peat resources of Ontario,
2) the suitability of the processes to Ontario,
3) the potential for fuel substitution,
4) the level of development of the required technology,
5) the cost of developing the potential applications, and
6) the experience of others in various parts of the world.

Within the limitations of the data available it was felt that the applications selected had significant potential and were worthy of further investigation. The eight selected are identified and described in Section 5.3 of this Part. In Section 5.4 the costs of competing fuels that have been used in the analyses are identified.

Each of the alternative applications is discussed separately in Sections 5.5 to 5.12. The discussions are broken into four distinct elements. The first discusses the markets served and the products produced. The second discusses the peat that is utilized under the conditions specified, and the production methods used for the potential application. The third segment deals with the identification of potential markets for the products specified. The fourth segment examines the viability of the application by comparing it with existing products in the markets identified.

The Part concludes with a review and synthesis of material presented relative to the eight applications examined. The preferred applications are identified and areas where effort could most usefully be expended to develop the peat resources of the province are specified.

5.2 POTENTIAL USES OF PEAT

As discussed in Section 2.2.1 of this report, peat is of two distinct types; horticultural peat and fuel peat. The two types of peat are different in both their chemical and mechanical properties making them suitable for different uses. A representative list of the major uses for peat is given in Table 5-1.

Horticultural peat is generally used in agricultural applications, though non-agricultural uses are being developed. The agricultural uses of horticultural peat vary with the main use being as a soil enricher. The addition of horticultural peat to a soil increases its humus content, its ability to hold moisture and improves its aeration. As well as being used as a soil additive to improve the soil's qualities as a growing material, horticultural peat is used also as a growing medium in greenhouses, and by household gardeners as a starting medium. Peat is often packaged in small quantities so that the environment, (water and nutrients) of each seed can be separately controlled. This concept is often taken a step further with small packages of peat with embedded seeds being produced for the home gardener. Horticultural peat is also used in the production of peat pots and seed carriers.

The non-agricultural uses of horticultural peat are at present focussed on pollution control. As a physical filter or addition to an existing filter peat is effective in removing suspended solids from aqueous effluents and reducing the sludge clogging of traditional filters. This ability is based on the peat's porous physical structure. The physical properties of the peat make it effective in the control of oil spills as it has a very high absorbency with an 82 kg bale (400 ℓ) being capable of absorbing 470-560 ℓ of oil.

Peat can also be used as a chemical filter and in such applications is extremely effective in removing heavy metals from aqueous effluent. Typical percentages of certain heavy metals, colour and cyanide removed from an industrial

TABLE 5-1. PEAT APPLICATIONS.

Non-Energy Related	
1. Agricultural Uses	Soil Enricher Peat Boards, Pots, Pellets, Etc.
2. Filtration	Chemical Processes Activated Carbon Metals
3. Absorption	Oil Spills Stable Litter
4. Anaerobic Digestion	
5. Insulation & Building Materials	
Energy Related	
1. Direct Firing	Process Heat Electricity Small-Scale Heating District Heating Combination of Above
2. Fuel Upgrading	Sod or Milled Peat/Thermal Drying Peat Derived Fuel (JP Energy) Coke Briquette Production (Outokumpu) Methanol Gasification—SNG or In-Situ Small-Scale Gasifier For Electricity/Heat Wet Pyrolysis, Solid Fuel Production
3. Other Chemical Transformation	Gasification—Methane & Liquid Hydrocarbons Liquefaction—Direct or via Gasification Biogasification— Methane

aqueous effluent using the peat based Hussong-Couplan Water Treatment System are shown below:

PARAMETER	REDUCTION
Colour	99.6%
Cyanide	100.0%
Chromium (+6)	99.99%
Chromium (+3)	99.9%
Copper (+2)	99.9%
Iron	99.2%
Lead	99.6%
Nickel	99.9%
Zinc	98.9%
Antimony	98.3%
Mercury	99.9%

In addition, peat is effective in reducing the biological oxygen demand (BOD) and chemical oxygen demand (COD) of aqueous effluents. It is used to treat aqueous effluents from slaughter-houses and meat packing plants because they are both high in BOD and COD. The aqueous effluents of producers of fine papers and textiles often contain dyes that in general are difficult to remove because they are stable with respect to light and oxidizing agents and are thus resistant to aerobic digestion. Peat is effective in removing these dyes from the effluent. Under some circumstances the spent peat can be burned without releasing toxic chemicals to the environment. The disposal of spent peat that cannot be burned is presently being researched.

Fuel peat is used, as its name suggests, primarily as a fuel, but it is also used as a feedstock in the production of certain other products. As a fuel, peat can be used as mined or after upgrading has been carried out. When used for heat the as mined fuel peat is direct fired in furnaces for space heating using a forced air, hot water or steam distribution system or in industrial boilers for the production of process heat. When used for the generation of electrical power, as mined fuel peat is burned in either an electrical generating station to produce only electricity or in co-generation facilities to produce both heat and electricity. The use of fuel peat for the generation of electrical power as considered in this report is primarily aimed at the displacement of other fossil fuel. If a unique, isolated load is expected to develop in the province, consideration should be given to using the direct combustion of peat in either an electrical or a co-generation facility to supply the needs of the load identified.

Mined sod peat can be processed to increase significantly its heating value per unit weight and per unit volume. This allows the peat to be transported longer distances and to be used in furnaces that require a fuel with a high heating value (Btu/lb). The as mined fuel peat can be processed into a variety of products including methanol, synthetic natural gas and coke. The methanol can be used as a gasoline additive, as a liquid fuel, or as a chemical feedstock. The synthetic natural gas can be used as a heating fuel or in diesel generators for the production of electric power. The coke produced from peat is chemically of a higher quality than coal based coke. It can be used as a reducing agent by the chemical and steel industries and it can be used as a binder in the production of iron pellets which are used by the steel mills.

5.3 DESCRIPTION OF THE POTENTIAL APPLICATIONS

In this section the eight potential applications selected for investigation and discussion are defined and briefly described.

1) HORTICULTURAL PEAT PRODUCTION FOR AGRICULTURAL USES. The production of bagged horticultural peat for both the domestic and export markets.

2) SMALL SCALE SOD PEAT PRODUCTION FOR SPACE HEATING. The production of sod peat on a small scale by an individual for local consumption in multi fuel and/or solid fuel furnaces, fireplaces and wood stoves.

3) SOD PEAT PRODUCTION FOR RESIDENTIAL AND NON-RESIDENTIAL SPACE HEATING. The production of sod peat on a commercial scale (25,000 to 100,000 tonnes per year) for use as a heating fuel by residential and institutional users.[1]

4) SOD PEAT PRODUCTION FOR INDUSTRIAL PROCESS HEAT GENERATION. The production of sod peat at a commercial scale for use by industry for the production of process heat.[1]

5) SOD PEAT PRODUCTION FOR POWER GENERATION USING A SMALL SCALE PEAT GASIFIER. The gasification of sod peat and the combustion of the gas produced in diesel generators to produce electricity and heat in remote communities.

6) SOD PEAT PRODUCTION FOR COKING. The production of coke, and as byproducts, electricity and heat, from sod peat at a single, large scale facility.

7) SOD/MILLED PEAT PRODUCTION FOR USE IN DISTRICT HEATING. The production of heat from sod or milled peat for use in a district heating system. If sod peat is used, the possibility of distributing sod peat to potential users not served by the district heating system is discussed.

8) WET MINING/WET CARBONIZATION FOR PREPARATION OF A PEAT DERIVED FUEL USED IN POWER GENERATION. The production of a pelletized or powdered peat-based fuel using wet mining technology and the "J.P. Energy" process for use in a power generating station.

The decision process employed to select the eight applications is based on the six criteria outlined in the Introduction and other considerations particular to the process involved. Primary consideration was given to the scale of the investment required and the availability of cost and market data. This eliminated several of the larger scale processes involved with emerging technologies. In some cases processes were rejected because they required climate or mining methods unsuitable to Ontario.

In addition, two applications were included which involved processes that are currently in the development state; covering both large-scale and small-scale mining operations and investment requirements. These processes, although under development, have reasonably well defined cost estimates available and can be readily applied to existing markets, allowing overall cost comparisons to be made.

The eight potential applications have been selected so that a large number of the markets identified in Section 5.2, which specified the potential uses of peat, are considered. The applications are based on processes that are described in detail in Part 4. The technical viability of these eight applications is felt to be reasonably high but their inclusion in the above list is not intended to imply that they are commercially viable. The preliminary feasibility of each potential application is investigated in Sections 5.5 to 5.12 to identify those which warrant further more detailed study.

[1]The production from a commercial scale mine does not have to be exclusively for potential application 3 or 4. The output of a single mine could be used by the customers of both potential applications. Thus the demand for peat under potential applications 3 or 4 could in combination justify a commercial scale mine.

5.4 COMPETING FUELS

Six of the potential applications of peat specified for consideration in this study are involved with the production of heat. Heat can of course be generated by the combustion of a number of fuels and by electrical means. This section specifies the prices of competing fuels that are used in comparisons. The costs identified are expressed in mid-1981 dollars. The comparisons carried out use the mid-1981 dollar figures specified below. This use of constant prices for the competing fuels does not allow for any relative escalation of the prices specified. This makes the analyses presented somewhat conservative because it could be expected that the costs of producing peat will rise less rapidly than the prices of competing fuels, since the resource is indigenous and the costs will tend to be of a more controllable nature.

5.4.1 FUEL OIL

The cost of fuel oil used in this study is $0.26/ℓ which is representative of prices being paid at mid-year 1981 for fuel oil delivered to various locations in the province. Where the price of fuel oil in a particular location, specifically identified for consideration, differs significantly from the value specified above, the local price will be identified and utilized in the cost evaluation of that alternative. The heating value of fuel oil is assumed to be 18,500 Btu/lb for the purposes of this study.

5.4.2 NATURAL GAS

The cost of natural gas used in this study unless otherwise specified (see fuel oil) is $3.25/MCF, which is an approximation of the cost of gas to a large industrial user. The heating value of natural gas is taken to be 1 MM Btu/MCF.

5.4.3 COAL

The cost of coal has been taken for the purposes of the investigation into the potential use of peat by the cement industry to be $60/tonne. This estimated cost is based on work carried out during a recent study to estimate the cost of Appalachian coal delivered to Ontario with an assumed heat content of 11,000 Btu/lb. The cost of coal for thermal power plant use is based on the current quality and cost estimates of Ontario Hydro for thermal coal delivered to Thunder Bay which is $30/tonne and a heat content of 7,000 Btu/lb.

5.4.4 ELECTRICITY

The cost of electricity used in this report unless otherwise specified (see fuel oil) is 2.57 ¢/kWh which is the bulk rate to electrical distributing companies in Ontario during 1981, at a voltage level of 230 kV and an annual load factor of 80%.

5.4.5 PEAT

Two types of fuel peat are considered in this report: sod peat and milled peat. Because the production rates achievable for both types of peat are heavily influenced by climate, they have been estimated for five regions of Ontario with differing climates. The estimated costs of peat from these regions, which are developed in Section 3, are shown in Table 5-2.

TABLE 5-2. PRODUCTION COST OF FUEL PEAT (MID-1981 DOLLARS/TONNE, ADJACENT TO BOG).

	Estimated Production Cost	
Climatic Region	**Milled Peat**	**Sod Peat**
Southern Ontario (Ottawa - Barrie)	18	31
Central Ontario (North Bay - Sudbury)	22	35
Western Ontario (Fort Frances - Kenora)	22	35
Northern Ontario (Kirkland Lake - Timmins)	24	38
Hudson Bay Lowlands	n/a	62

The cost per mile of transporting peat is high due to its bulk and if transportation distances are long can become a significant portion of the total cost of the peat. The cost of transportation for sod peat is about $0.18/tonne mile and for milled peat is about $0.25/tonne mile. Sod peat is assumed to have a moisture content of 35% and a heating value of 7,000 Btu/lb while milled peat is assumed to have a moisture content of 50% and a heat content of 5,000 Btu/lb.

The cost of sod peat used in cost comparisons is $38.60 which is based on a cost of sod peat for Westen Ontario of $35.00 and a haulage distance of 20 miles at $0.18 per mile.

A comparison of these fuels on a dollars per million Btu's basis has not been presented because the ratio of heat input to heat output varies by fuel, type of conversion equipment and equipment size.

5.5 HORTICULTURAL PEAT PRODUCTION FOR AGRICULTURAL USES

5.5.1 GENERAL

Under this scenario a horticultural peat mine would be developed to produce bagged sphagnum peat moss in Ontario for domestic and export markets. Ontario has significant horticultural peat resources, has good access to transportation corridors to the United States and is itself a net importer of horticultural peat.

5.5.2 THE PRODUCT AND PRODUCTION METHODS

Canadian sphagnum peat is well recognized as a superior grade horticultural peat and has a high water retention factor. In general, sphagnum peat is mined as milled peat and air dried to 50% moisture, compressed at a ratio of 2:1 and packaged in plastic bags as bales of 2, 4 or 6 cubic feet.[1] Peat produced in this manner is often used to improve the quality of soils used in nurseries, or golf courses and by domestic gardeners.

In Europe other horticultural peat products have been developed and are now marketed with great success, including fertilized horticultural peat which is available in three coarseness/fertilization combinations for growing vegetables, potted plant propagation, and sowing. Peat moss bales are also available with only lime added.

[1] For a more detailed description of the production of bagged sphagnum peat see Part 3.

Other agricultural horticultural peat products include peat sheets and peat growing boards. Peat sheets are peat which has been compressed and dried to reduce the bulkiness and weight of a given quantity of peat solids and to lower transportation costs. The peat sheets are used by spreading them on the ground where the peat is required and adding sufficient water to swell and break the peat sheet apart. Peat growing boards are compressed peat sheets (112 × 20 × 4 cm) and are generally packaged in opaque plastic bags. This product is popular in nurseries because with the addition of sufficient water the peat expands and the growing medium is then ready to accept plantings and is neat to use. As each expanded bag forms a separate growing unit, it is easy for the grower to control the amount of water and fertilizer used. Packaged peat is also available for the domestic gardener, with each package suitable for planting one seed.

5.5.3 POTENTIAL MARKETS

Canada produces approximately 500,000 tonnes of horticultural peat per year which represents about 5% of the total free world production. Canada exports approximately 80% of its horticultural peat and by far the largest export market is the United States with much of this Canadian peat being shipped via Niagara. The preliminary 1980 Canadian production figures are shown in Table 5-3. The Provinces of Quebec and New Brunswick account for approximately 70% of Canadian production while Newfoundland and Prince Edward Island have no production. Ontario has the lowest production of the producing provinces, and a review of the production records for the past 5 years (Table 5-5) shows that peat production in Ontario has been declining annually until 1979 with the trend reversing in 1980. The market value per tonne has shown an average steady annual increase of about 16% over the period 1976-1979 inclusive.

The Canadian market is estimated to be about 98,000 tonnes per year (Table 5-4) of which at least 40% or 39,000 tonnes are estimated to be consumed in Ontario. This value of 40% is based on an extrapolation of data on the distribution of population and vegetable farming operations in Canada. The extrapolation assumes that the consumption of horticultural peat increases as the population and the amount of vegetable farming increases. Because only about 8,000 tonnes of horticultural peat were produced in Ontario in 1980 (preliminary Statistics Canada estimate) there would appear to be a potential for about 30,000 tonnes of locally produced horticultural peat per year to displace peat imported into the province.

Bagged horticultural peat produced in Ontario can be expected to be competitive with peat shipped into the province because of the high cost of transporting peat. Ontario's location close to the main Canada-U.S. transhipment point gives an Ontario producer good access to the U.S. Market.

The production of peat products for use in pollution control applications has not been included here because the market for bagged peat is large (see below) and the development of markets for these pollution control related uses would entail the commitment of significant resources that might best be used in other areas.

Horticultural peat is generally marketed in a compressed state in 2, 4 and 6 cubic foot plastic bales. One tonne of loose 50% moisture horticultural peat will make about 26 bales of the 6 cubic foot size when compressed at a ratio of 2:1. For milled horticultural peat production costs of about $18.00 to $24.00 per tonne, the range of costs estimated for Ontario, the cost of producing horticultural peat is less than $1.00 per bale. The cost of the plastic bag and closure, the operating costs of the bagging plant and other overheads total about $2.00 per bale. Thus, in very general terms, the cost per bale is about $3.00 bogside, (i.e. excluding inventory and shipping costs). These inventory and shipping costs can vary depending on the location of markets, transport arrangements, etc., however, the wholesale price of peat in southern Ontario in 1981 is in the $4.50 to $5.50 range. This differential of $1.50 to $2.50 between the costs of production and the wholesale price for horticultural peat would suggest that horticultural peat produced in Ontario should be able to compete on a price basis and given the quality of the peat resource (see preceding discussion) there appears to be justification for the establishment of horticultural peat mining operations totalling 30,000 tonnes per year. This does not include any allowance for the market that might develop for the new peat products identified in Section 5.2.

TABLE 5-3. 1980 HORTICULTURAL PEAT PRODUCTION IN CANADA (PRELIMINARY)

	Tonnes	$ Value
Newfoundland	—	—
Prince Edward Island	—	—
Nova Scotia	12,000	1,625,000
New Brunswick	124,000	9,707,000
Quebec	217,000	14,748,000
Ontario	8,000	815,000
Manitoba	42,000	5,050,000
Saskatchewan	10,000	700,000
Alberta	49,000	5,912,000
British Columbia	26,000	3,869,000
	488,000	42,426,000

Source: Statistics Canada

TABLE 5-4. ESTIMATED HORTICULTURAL PEAT IMPORTS INTO ONTARIO (1980).

	Tonnes
Canadian Production	488,000
Canadian Imports	negligible
Canadian Exports	390,500
Canadian Consumption (by subtraction)	97,500
Ontario Consumption*	39,000
Ontario Production	8,000
Estimate of Horticultural Peat Imported into Ontario	31,000

*Based on previous studies, assumed to be 40% of Canadian consumption.

TABLE 5-5. REVIEW OF ONTARIO HORTICULTURAL PEAT PRODUCTION.

	Tonnage[1]	$ Value[2]	$ Value[2]/Tonne
1976	11,000	870,000	$ 79.1
1977	9,000	790,000	$ 87.70
1978	7,000	664,000	$ 94.90
1979	6,000	740,000	$123.30
1980[3]	8,000	815,000	$101.90

Note: 1 - At 50% moisture.
2 - Wholesale Value.
3 - The lower average value of peat production in 1980 is in part due to the inclusion in the figure of the production of a bulk peat production plant that commenced operations during the year. The bulk peat produced by this operation has a market value significantly lower than that of packaged peat.

Source: Statistics Canada.

It is estimated that a 250 ha peat operation and a triple line bagging plant would be necessary to produce 30,000 tonnes of peat per year. Bog preparation and mining equipment will cost in the order of $1,000,000 and the ancillary facilities, including bagging plant, office, maintenance buildings and inventory handling systems about $1,700,000.

The project would create about 20 jobs for equipment operators, mechanics and plant personnel and 5 administrative and supervisory positions. Some additional temporary labour would be required during the period June to September.

The absence of the suggested 30,000 tonnes per year of horticultural peat mining capacity at the present time may be due to a number of factors that increase the risk of horticultural peat mining, including the timing of initial production and identification of a suitable bog. The mine must be prepared in one year, the peat mined in the second and the product sold in the third. There exists the possibility that the second year might be wet, restricting production and reducing the revenues received in the third year. This potential variation in the actual cash flow from that projected can put the financial stability of such an operation in jeopardy. The cost of identifying a bog suitable for mining, and developing a mine plant for such a bog is significant. It is possible that a number of bogs will have to be evaluated to identify one suitable bog and as this identification process can take more than one season, there is a risk associated with the initial investments made in bog identification. Possibilities for reducing these risks are discussed in Section 5-13.

5.6 SMALL SCALE SOD PEAT PRODUCTION FOR SPACE HEATING

5.6.1 GENERAL

This scenario is concerned with the development of small, noncommercial, sod peat mining operations by potential sod peat users. It is envisaged that under this alternative, a farmer or rural resident would produce approximately 300 tonnes of sods per year from a nearby bog for use by himself and neighbours.

5.6.2 THE PRODUCT AND PRODUCTION METHODS

Under this alternative, a farmer or rural resident would mine sod peat during the summer. The sod peat would have a moisture content of about 35% and a heating value of 7,000 Btu/lb and be suitable for use in solid and multi-fuel furnaces. The production of sod peat on a 25,000 tonne/yr scale or larger is described in Section 3.3. The considerations outlined in that section apply for the proposed 300 tonne per year operation but equipment requirements are considerably less. It is assumed that farmers having standard farming equipment including a 50 to 100 H.P. farm tractor with a 3 point hitch, finger wheel rakes, rotovators, ditchers, and harrows need only purchase a sod cutter and a collecting machine to commence sod peat mining operations. Some modifications of the tractor including dual wheeling and the addition of more hydraulic equipment may be necessary. It is estimated that a time commitment of 60-90 hours/yr would be sufficient to mine 300 tonnes annually. As only 2 ha would need to be mined for this production level, actual bog preparations costs are small.

5.6.3 POTENTIAL MARKETS

Most rural areas in Ontario are not serviced by natural gas companies because of their distance from main distribution lines. Because of this, most rural residents use fuel oil or wood for heating the (farm) house and secondary structures. Many people in rural communities have dual fired oil-wood furnaces and those with only oil are expected to include a unit capable of burning solid fuel if a ready supply exists. Based on the above discussion, it can be seen that any group of about 10-20 rural residences (depending on farmhouse size and age, and the area of secondary structure heated), located near a fuel peat bog is a potential user of fuel peat under this scenario.

It is expected that a large number of these potential users (groups of farms and rural residences) would convert to peat if they were aware of the option of burning peat, especially in areas where wood is becoming scarce. However, the capital investment required might slow the rate of development of this type of operation. The capital investment that a farmer would need to make to start production of 300-400 tonnes per year is about $23,000 as shown in Table 5-6.

Operating costs to produce 300 tonnes per year are proportional to the tractor/operator time it takes to cut the peat and collect it when it is dry. The sod equipment is capable of cutting over 100 tonnes per day and the collection equipment operates somewhat faster. These production rates will not be achieved by the farmer because he is expected to have only 1 ha under production. Based on the estimated total operating time per year of 60 to 90 hours and using a total labour and equipment operating cost of $35.00/h, the total annual operating costs will be $2,100 to $3,150. Capital financing charges and bog preparation would represent an additional charge of $5,490 per year based on an equipment life of 10 years and a financial rate of return of 20%: The total cost of the sod peat produced would be between $7,590 and $8,640; $1.63 and $1.87 per million Btu. Firewood, by comparison, would have to cost less than $31.00/cord to match this cost of energy.

TABLE 5-6. CAPITAL COST ESTIMATE FOR SOD PEAT EQUIPMENT.

Item	Cost 1981 $
Equipment on Hand	
Tractor	—
Bucket for Tractor	—
Ditcher for Tractor	—
Wagon	—
Leveling Blade	—
Rotovator	—
New Equipment	
Sod Cutter	12,000
Sod Collector	8,000
Modifications to Tractor (Dual Wheels and Extra Hydraulics)	3,000
TOTAL	23,000

It may be argued that the cost of firewood is minimal because a farmer produces it in his spare time from a resource that he owns. However, when he burns the wood he is foregoing the funds he presumably could receive from the sale of that wood. The present selling price and thus the opportunity cost of a cord of wood is approximately $50.

5.7 SOD PEAT PRODUCTION FOR RESIDENTIAL AND NON-RESIDENTIAL SPACE HEATING

5.7.1 GENERAL

Under this potential application a sod peat mining operation would be established to supply sod peat to residential and non-residential users for space heating.

The discussion of this potential application investigates, for the residential market, the type of fuel at present being used for space heating, the cost of space heating and the likelihood of the adoption of peat as a fuel. The potential non-residential market is discussed in general terms, with particular attention being paid to the potential for peat use by schools and hospitals.

5.7.2 THE PRODUCT AND PRODUCTION METHODS

The production of sod peat, and the nature of bogs suitable for sod peat production have been described in Sections 3.3 and 2.3.3, respectively. In summary, sod peat is produced from a bog that contains highly humified peat suitable for combustion. This peat is mined in a two-stage process. In the first stage, a sod cutter cuts the peat vertically from the bog and forces the cut peat through an extruder. The extruder is generally designed to produce cylindrical sods 6 to 10 cm in diameter and 10 to 20 cm long. The actual diameter and length are controlled by adjusting the size and shape of the extrusion nozzle. The sods after being cut are left to dry in the sun. After the sods have dried sufficiently, they are collected using a specially designed sod collector. When harvested, the sod peat has a calorific value of about 7,000 Btu/lb and a moisture content of 30%.

5.7.3 RESIDENTIAL

5.7.3.1 POSSIBLE MARKETS

The residential sector's energy requirements can be broken down into three major groups, space heating, water heating and other, such as appliances and lighting. The space heating requirement is about 75 percent and the water heating requirement about 15 percent of the total energy demand.[1]

[1] Based on Statistics Canada, 1976 Census data.

TABLE 5-7. PRINCIPAL RESIDENTIAL HEATING EQUIPMENT IN ONTARIO (000's OF UNITS).

	1976	1977	1978	1979	1980
Total Households	2622	2637	2741	2813	2910
Steam or Hot Water Furnaces	603	626	664	665	618
Hot Air Furnaces	1614	1625	1642	1675	1816
Heating Stoves	76	91	79	84	86
Electrical	304	284	343	372	378
Cook Stoves or Ranges	16	—	10	9	—
Other	—	—	—	9	—

Source: Statistics Canada.

TABLE 5-8. PRINCIPAL RESIDENTIAL HEATING FUEL IN ONTARIO (000's OF UNITS).

	1976	1977	1978	1979	1980
Total Households	2622	2637	2741	2813	2910
Oil or other liquid fuel	1095	1060	1102	1065	1029
Piped Gas	1183	1228	1222	1293	1398
Bottled Gas	17	18	16	17	12
Electricity	304	303	365	400	406
Coal or Coke	—	—	6	—	—
Wood	19	21	29	34	59
Other	—	—	—	—	—

Source: Statistics Canada.

Peat is a potential fuel for both space and water heating applications, though generally it is only used for water heating when the water heater is integrated with the space heating system. The use of peat to fire such integrated systems has not been considered here, rather its use in space heating applications only is considered.

Residential buildings in Ontario are generally heated by steam, hot water or hot air generated in a central furnace fired by oil, natural gas, and/or solid fuels such as wood and in a few instances, coal and peat. Some residences do not use central furnaces for heating but use fireplaces, distributed heating stoves, distributed electrical heaters, or cooking stoves instead. The fuels and heating systems used in Ontario residences during the period 1976-1980 inclusive are shown in Tables 5-7 and 5-8. Because the data available on residential space heating do not show the variation in fuel and equipment used by geographic region within Ontario, it is not possible to identify particular areas where demand for peat-fired furnaces might develop.

The Government of Saskatchewan has considered the potential for heating residential structures in Northern Saskatchewan of sufficient interest to have commissioned several studies to identify and outline its potential. Currently, a small-scale demonstration program is being considered which will include testing of locally produced peat sods in domestic furnaces in several dwellings in a northern Saskatchewan community.

TABLE 5-9. ANNUAL REDUCTION IN FUEL EXPENSE CONVERTING FROM 100% FUEL OIL TO 80% PEAT AND 20% FUEL OIL FOR RESIDENTIAL HEATING.

Alternative	Fuel	Quantity	Unit Cost (mid-1981 $)	Total Cost (mid-1981 $)
100% Fuel Oil	Fuel Oil	3,200 ℓ	0.26/ℓ	833
80% Peat	Peat	7.4 tonnes	38.6/tonne[1]	286
20% Fuel Oil	Fuel Oil	640 ℓ	0.26/ℓ	167
			SUB TOTAL	453
Estimated Reduction in Annual Fuel Expense				380

[1] Based on a cost at mine site of 35 mid-1981 dollars per tonne and transportation 20 miles at a cost of 0.18 mid-1981 dollars per mile.

Piped natural gas is currently the preferred fuel because of its low cost relative to fuel oil and its high level of convenience relative to peat, coal and wood. Thus, this section deals only with the potential to convert fuel oil users to peat in areas where piped natural gas is not available.

The rest of this section discusses the potential use of peat by an average home in Ontario (area 140 m^2), and the number of such 'average' homes that would be required to support a sod peat mine. If an average home were heated with fuel oil, it would use approximately 3,200 ℓ annually. Recent work has shown that if a home were to be heated with peat, it is most reasonable to supply 80% of the heat required with peat and 20% with fuel oil. In estimating the quantity of peat required to supply 80% of the home's heat requirements, it is assumed that peat is ten percent less efficient than fuel oil on a Btu basis. Under these assumptions, the annual fuel requirements of a peat heated home would be 7.4 tonnes of sod peat (7,000 Btu/lb, 35% moisture) and 640 ℓ of fuel oil.

The cost of converting from a fuel oil furnace to a multi-fuel furnace is approximately 1,000 mid-1981 dollars. The estimated annual reduction in fuel expenses obtained by switching from 100% fuel oil to 80% peat/20% fuel oil is 380 mid-1981 dollars, as shown in Table 5-9. Using the above estimates and assuming that the home owner's real cost of funds is 10%, that there is no relative escalation between the prices for fuel oil and peat and that the furnace lasts 15 years the net present value of the investment made in the multi-fuel furnace is about 1,890 mid-1981 dollars.

Under the federal government's off-oil program, the homeowner can obtain an $800 grant to cover some of the costs of conversion. If the homeowner took advantage of this potential, he would increase the net present value of the investment to 2,650 mid-1981 dollars. Because of the large estimated net present value of the investment in peat-fired heating, and the short payback period (2½ years) one might expect that a large number of homeowners without access to piped natural gas would convert to peat if it were made available at a price in the indicated range.

The smallest commercially viable fuel peat operation is about 5,000 tonnes per year, thus, even the smallest fuel peat operation would produce enough peat to supply about 680 houses. On the basis of the above discussion, it would appear that small towns in northern Ontario are good potential markets for sod peat for residential space heating. The residential market in such towns may well be less than 680 units. If so then it may be possible to develop sufficient additional demand from institutions (section 5.7.4) such that a sod peat mine could be justified. Further field investigation is required in the areas of marketing, distribution, and consumer response for this potential to be assessed at a more exact level.

5.7.4 INSTITUTIONAL

5.7.4.1 INTRODUCTION

Institutions have been specifically identified under this alternative because of the size of each building's heating load and the small number of decision makers who would have to be convinced of the economics of partial peat-firing to achieve significant peat usage. The size of the heating load is a benefit because the sod peat from a given mine has to be distributed to only a limited number of locations and the user can more likely justify the installation of automatic peat handling systems, reducing the negative attitude toward peat that might exist because of its bulk. Schools and hospitals without access to natural gas will be specifically reviewed as potential markets but the concentration on these two potential users should not be considered as an indication that other institutional users such as universities, government buildings and large office buildings should not be considered in further studies.

5.7.4.2 POTENTIAL MARKETS

HOSPITALS. There are, at present, 231 hospitals operating in the province. They range in size from the Toronto General with 1074 approved beds as of March 31, 1980 to the Chesley and District hospital with 19 approved beds. The average size is 206 beds with a total number of approved beds as of March 31, 1980 of 47,510. The floor area of a hospital is generally proportional to the number of beds with each bed representing approximately 1,000 square feet of space. Thus, the total floor area of the hospitals in Ontario is approximately 47.51 million square feet.

In discussions with the planning branch of the Ministry of Health, it was determined that the average heating load for hospitals in Ontario is approximately 52 kWh thermal/sq ft yr. If a 50 bed hospital converted to peat-firing for 80% of its heating requirements, it would utilize each year about

TABLE 5-10. CONSUMPTION OF NATURAL GAS AND OIL BY SCHOOLS IN ONTARIO JULY 1, 1978—JUNE 30, 1979

ALL SCHOOLS BY DISTRICT[1]

District	Floor Area (000's m^2)	Consumption		Number of Schools
		Natural Gas (millions ft^3)	Oil (000's gallons)	
Central	11153	4183	34600	
Eastern	2394	463	8625	
Mid-Northern	867	331	3047	
Northeastern	703	573	816	
Northwestern	482	403	490	
Western	2627	1852	3871	
	18222	7805	51449	4650

ALL SCHOOLS IN SELECTED BOARDS[1]

District	Floor Area (000's m^2)	Consumption		Number of Schools
		Natural Gas (millions ft^3)	Oil (000's gallons)	
Bruce County	93	—	412	33
Carleton	362	35	1144	66
Carleton RCSS[2]	128	8	532	45
Durham	394	146	967	99
East Parry Sound	41	—	197	18
Frontenac (Kingston)	178	73	755	51
Lake Superior	19	—	163	8
London/Middlesex	95	28	368	38
Manitoulin	20	—	128	7
Middlesex	101	41	393	33
Nipissing	124	119	133	32
Nipissing RCSS[2]	84	46	138	33
Ottawa	609	68	2568	84
Ottawa RCSS[2]	200	78	640	74
Peterborough	178	25	614	46
Renfrew	161	50	441	36
Stormont (Cornwall)	166	18	641	53
Sudbury	311	189	652	71
Sudbury Dist. RCSS[2]	181	73	613	75
West Parry Sound	35	—	118	14

Notes: 1—Includes only schools that reported fuel consumption to the Ministry of Education of Ontario.
2—Roman Catholic Separate School.
Source: Ministry of Education, Energy Group.

600 tonnes of peat assuming that peat-firing is 10% less efficient than oil-firing.

SCHOOLS. There are about 4,650 schools (elementary and secondary) in Ontario. These schools at present use natural gas and/or fuel oil for space heating. Table 5-10 shows for all schools in Ontario which reported energy use data to the Ministry of Education the total floor area, natural gas and fuel oil consumption by region and for selected school boards. The total amount of fuel oil used in 1978-79 was 51.447 million gallons and of natural gas was 7,805 million ft^3. As the July 1981 price of $1.19 per gallon for heating oil and $3.25/MCF for natural gas, this represents an annual expenditure of 85.387 million mid-1981 dollars.

Both hospitals and schools are utilizing natural gas and fuel oil for heating. The relative costs of firing with the following four fuel combinations: 100% fuel oil; 80% peat/20% fuel oil; 100% natural gas; 80% peat/20% natural gas are shown in Table 5-11, for a typical hospital in Ontario.

The table indicates that firing with 80% peat/20% natural gas is the cheapest, followed by 100% natural gas, then 80% peat/20% fuel oil and lastly 100% fuel oil. This would suggest that all hospitals and schools should consider burning 80% peat/20% natural gas to minimize fuel costs. Table 5-11, however, does not make any allowance for conversion costs, fuel handling costs or the preceived cost of handling a bulk fuel. Thus, it should not be assumed, on the basis of Table 5-11 that all hospitals and schools should change to 80% peat/20% natural gas where natural gas and peat are available, rather the total cost of this alternative should be carefully investigated.

TABLE 5-11. ESTIMATED COST OF HEATING FUEL REQUIRED TO HEAT A TYPICAL FIFTY-BED HOSPITAL IN ONTARIO.

Fuel Combination	Quantity	Unit Cost ($)	Total (000 $)
80% Peat	568 tonnes	38.6	22.52
20% Natural Gas	56 m^3	0.092	6.43
TOTAL			28.95
100% Natural Gas	279 m^3	0.092	32.13
80% Peat	568 tonnes	38.6	21.92
20% Fuel Oil	50,200 litre	0.26	12.73
TOTAL			34.65
100% Fuel Oil	251,000 litre	0.26	63.78

The cost differential between 80% peat/20% fuel oil and 100% fuel oil, however, is sufficient to suggest that a case can be made for conversion to 80% peat/20% fuel oil where natural gas is not available.

The distribution of natural gas in Ontario is the responsibility of three firms, Union Gas, Consumers' Gas and Northern and Central Gas with each of these firms supplying a different portion of the province. In each firm's region there are significant areas of the province that distribution pipelines do not reach. In areas that the distribution pipelines do reach, local conditions, particularly soil conditions, often preclude the economic distribution of gas to segments of an area that is supplied with natural gas. Because of these factors it is not possible to make a generalized statement about the location of those who could be expected to switch due to natural gas not being available.

On the basis of the above discussion, it is expected that those hospitals and schools now heated with natural gas will continue to use natural gas. Those who have access to piped natural gas but are using fuel oil are expected to convert to natural gas in the near future because of the off-oil program and the reductions in fuel expenses that can be achieved. The reductions that can be achieved by switching from 100% natural gas to 80% peat/20% natural gas are not expected to be sufficient to cause this conversion because of the small difference in fuel cost, the cost of conversion and the lack of experience in Canada with peat-fired heating systems. Rather it is expected that fuel oil users are the potential market within the school and hospital markets.

For instance, on Manitoulin Island, there is no piped natural gas and there is sod peat which could be used to heat the seven schools on the island and the 52 bed hospital at Little Current. The potential annual demand for sod peat for these schools with 20,000 m^2 of floor space is approximately 1,120 tonnes. The annual demand generated by the hospital if it converted to 80% peat/20% fuel oil firing would be 620 tonnes. This total of 1740 tonnes is insufficient to justify a sod peat operation, however, this potential load in combination with other loads such as government buildings and housing on the island might generate sufficient demand to justify a sod peat operation. In particular, the hospital at Mindemoya could be considered for conversion.

If the Manitoulin school board converted to 80% peat/20% fuel oil firing, it would reduce its annual heating expenses by $69,500 (46%). This reduction would occur because fuel oil purchases would have been reduced by 102,000 gallons. The cost of multi-fuel furnaces that would be used for an average school in the Manitoulin board would be approximately $20,000. Thus, the investment in seven multi-fueled furnaces would be recovered through fuel savings in about 2 years.

There are other school boards and hospitals in the province in similar situations. A large portion of those without access to piped natural gas could be expected to switch to peat if a demonstration project were to prove its feasibility, sod peat were available at prices close to those identified in the report and space considerations did not preclude the use of peat.

5.8 SOD PEAT PRODUCTION FOR INDUSTRIAL PROCESS HEAT GENERATION

5.8.1 INTRODUCTION

Industry uses heat in a large number of processes. The process heat is most often generated through the combustion of fuel oil, natural gas, coal, wood and waste products such as wood chips, bark and production gases.

In this section, five industries that used on an energy basis, approximately 28% of the fuel oil and natural gas utilized in Ontario during 1979 are identified and discussed. These five industries were selected for review because they use such a large portion of the energy consumed by the 150 industries in Ontario.

Further studies could investigate the potential applications of peat for smaller industries, when one plant would use the production of a local bog. Such a study would require site specific work that is outside the scope of this study.

The discussion of each industry covers the size of the industry, the processes of interest and the estimated potential demand for peat. The material presented in these discussions is based on the consultant's experience gained in other studies. The economics of converting from the existing fuel to peat have not been estimated because of the effort that would be required to develop even a rough approximation of the conversion costs, site specific peat costs and differential operating costs associated with the conversion. Thus, the potential demand identified refers to uses

that peat could fulfill but does not indicate that peat is or is not competitive on a total cost basis for these applications.

The five industries examined consumed 1687 million litres of fuel oil and 4202 million m^3 of natural gas in 1980. Their total energy use for process heat is equivalent to 12 million tonnes of sod peat, distributed as follows:

- Industrial chemicals (4.3 tspe)[1];
- Pulp and paper mills (3.3 tspe);
- Iron and steel mills (3.2 tspe);
- Smelting and refining (0.5 tspe); and
- Cement manufacturing (0.7 tspe).

5.8.2 INDUSTRIAL CHEMICALS

Manufacturers of industrial chemicals used 13.9 percent of the industrial energy consumed in Ontario during 1979. The industry in 1979 consumed 426,000 m^3 of heavy fuel oil and some 1,412,000 m^3 of natural gas, which is equivalent to approximately 4.31 million tonnes of peat.

The industrial chemical industry consumes carbon and hydro-carbon fuels for two purposes. The largest use is as a fuel to generate heat which is generally supplied in the form of steam to initiate or support chemical reactions and a smaller amount is used as feedstock for the production of chemical products.

The chemical industry in Ontario is concentrated in the populated area of Sarnia. The need for larger (than existing oil fired) boilers, peat handling equipment and peat stock piles in a restricted area make the use of peat by the chemical industry generally undesirable. In addition, there are no significant peatlands in the Sarnia area.

Reflecting the above considerations, and based on 1980 consumption levels of fuel oil, natural gas and coal for the industry, it is expected that there will be no significant demand for peat in the industrial chemicals industry in the near future.

5.8.3 PULP AND PAPER

The 29 pulp and paper mills in Ontario are very large consumers of energy consuming 9.4% of the industrial consumption, second only to industrial chemicals.

The production of paper products requires the reduction of timber into wood pulp through chemical and mechanical means and the formation of final paper products on a paper machine. A wet paper mat is produced on the paper machine, which is subsequently dried through the use of steam. Electrical energy is required to operate the extensive mechanical equipment, and heat, in the form of steam, is required in the production of wood pulp and for drying. Most electric energy is purchased from outside, but steam is self-generated in steam boilers fired by a variety of fuels.

Heavy fuel oil and natural gas are the main sources of energy for the production of process heat, with minimal amounts of coal being consumed. Heat obtained from the combustion of wood waste or "hog fuel" in refuse burning boilers and the burning-off of impurities in chemicals used in the paper making process, supplies some 35% of total steam requirements for a typical kraft mill operation.

During 1979, some 1194 million m^3 of natural gas, equivalent to 2.7 million tonnes of peat, and 208,000 m^3 of heavy fuel oil, equivalent to 0.5 million tonnes of peat, were consumed by the industry in Ontario.

The estimated potential demand for peat in the pulp and paper industry of Ontario is forecast based on the estimated heat requirement for the production of a tonne of finished newsprint, a tonne of kraft paper and the proportion of this heat requirement that must be supplied from purchased fuels such as heavy fuel oil, natural gas and coal.

It is estimated that 8,000 pounds of steam are necessary to produce one tonne of newsprint and that 10,000 pounds are required per tonne of kraft paper. Purchased fuels such as heavy fuel oil, natural gas and coal combined typically supply some 75% and 40% of the heat required for the production of newsprint and kraft paper respectively. These purchased fuel requirements are multiplied by individual plant capacities and an average capacity factor of 90% to estimate ultimate peat demands. Actual requirements for specific mills would vary depending on the level of bark usage and individual operating characteristics. It is estimated that the total 1980 purchased fuel requirement for steam generation will be approximately 1.8 million tonnes of sod peat equivalent.

To determine the portion of this total that might be supplied by peat would require a detailed analysis of each plant. However, it should be noted that a plant such as the Boise Cascade plant in the Fort Frances–Kenora area would have a potential annual sod peat demand of 92,300 tonnes and there are significant identified sod peat resources in the area. Thus, the volumes involved are sufficient to justify a large scale peat mining operation and benefit from possible economies of scale.

5.8.4 IRON AND STEEL

During 1978, 11.4 million tonnes of steel were produced in Ontario. Heavy fuel oil and natural gas usage in the industry during the same year totalled 755 million ℓ and 1216 million m^3 respectively or some 3.2 million tonnes of peat equivalent.

The Canadian steel industry uses four methods to produce steel:

- blast furnace/open hearth furnace;
- blast furnace/basic oxygen furnace;
- scrap/electric arc furnace;
- direct reduction/electric arc furnace.

The traditional methods of producing steel utilize blast furnaces for the conversion of iron ore into molten iron and open hearth furnaces or basic oxygen furnaces (BOF) to produce steel. The BOF furnace is the more economic and constituted approximately 70% of the total steel making capacity from the two furnace types in Canada during 1978. These two methods of production had a capacity to produce 13.3 million tonnes of steel in 1978, with electric furnaces accounting for an additional 4.7 million tonnes of capacity.

Two areas where oil and gas are now being used could be considered for conversion to peat. First, the use of powdered peat as a substitute for oil and gas now being injected into the blast furnaces could be considered. However, the technology required for this application of peat is not proven.

Secondly, peat could be considered for use in direct reduction kilns. There are two reduction facilities in Ontario which have not operated since 1976 due to the high price of scrap iron. It is not expected that either plant will be used in the next few years and that any operation will be for limited periods of time.

It is felt that no significant market will develop for the use of peat in the iron and steel industry.

5.8.5 SMELTING AND REFINING

The smelting and refining industry in Ontario processes a wide range of non-ferrous metals, with copper and nickel being, by far, the most important in terms of volume and

[1] Tonnes of Sod Peat Equivalent.

energy consumption. Two major producers dominate the copper and nickel production in Ontario. During 1978 approximately 194,300 tonnes of copper and 97,400 tonnes of nickel were produced in Ontario.

The refining of copper and nickel is a three step operation. Concentrates are first roasted in furnaces to oxidize iron present in the ore before smelting. The oxidization process is an exothermic reaction requiring no sustained external energy source. Smelting is conducted in either reverberatory, electric or flash furnaces. The reverberatory furnace is generally fired by pulverized coal or heavy fuel oil. Gas can be used as a fuel source, but is less desirable. Flash furnace smelting requires only minimal external heat as the process, similar to the roasting process, obtains a significant amount of the necessary energy from an exothermic reaction. In the final stage, converting, air is blown into the melt to assist in the removal of impurities.

The potential peat consumption for copper and nickel smelting is estimated assuming a total heat requirement from fossil fuels of between 9 and 15 million Btu/tonne of metal produced in reverberatory furnaces. The lower and upper figures correspond to furnaces operating with and without oxygen enrichment. The only copper or nickel smelting plant in Ontario that could possibly utilize peat is the Inco metals plant in Sudbury. Based on the above heat requirement, this plant would utilize 514,000 tonnes of sod peat annually. The technical feasibility of this use of peat needs to be investigated.

5.8.6 CEMENT

Cement manufacturers in Ontario operate a total of seven plants, excluding grinding plants, with a total annual production capacity of 4.0 million tonnes of cement at the end of 1978. During 1979, the industry operated at a 70% capacity factor, producing approximately 4.5 million tonnes of cement.

The cement industry, although requiring significantly less energy in total than the largest industrial user in Ontario, Industrial Chemicals, consumes as much or more, than most operations on an individual plant basis.

Portland cement is produced by burning a finely ground mixture of limestone, silica, alumina and iron oxide in a rotary kiln. The kiln discharge, in the shape of round spheres, is a fused chemical mixture termed clinker, which is subsequently mixed with some 5 percent gypsum by weight and ground to a fine powder to form portland cement.

Two methods of production are now being used in Canada. The mixing of the clinker ingredients before entering the rotary kiln can be accomplished using either a wet or dry process. In the wet process, water is added to each ingredient forming a number of solutions which are mixed to supply the required composition. In the dry process, each material is ground and mixed without the addition of water, which must be removed by evaporation in the rotary kiln.

Heat is supplied to the rotary kiln through the combustion of heavy fuel oil, natural gas or coal. Coal is presently being used by four of the seven cement plants in Ontario, with 1977 annual consumption of some 400,000 tonnes equivalent to 680,000 tonnes of sod peat. During 1979, approximately 154,000 m^3 of natural gas and 118,000 m^3 of heavy fuel oil, equivalent to 650,000 tonnes of peat, were consumed by the industry in Ontario. The potential exists for the conversion of the cement plant located in Picton to peat fired operations. This is the only cement plant close to a peat supply, a requirement if peat is to compete with the current cost of coal.

The average heat requirements for the production of one tonne of portland cement during 1978 was some 1100 kilocalories using a dry process, which is used in the Picton plant. Applying these heat rates to the production capacity in Picton the potential demand for peat is estimated. Based on information obtained from industry sources, a capacity factor of 75% is assumed. The ultimate market for the use of peat at the Picton cement plant is estimated to be 296,000 tonnes. Because of its competitive price relative to coal, it is possible that peat will be able to capture a portion of this market.

5.9 SOD PEAT PRODUCTION FOR POWER GENERATION USING A SMALL SCALE PEAT GASIFIER

5.9.1 GENERAL

Under this alternative peat would be mined and gasified, providing a synthetic gas for use in a diesel generator. This potential application is designed for use in a remote community that currently depends on diesel generation for its electricity and is isolated from the main provincial power grid.

The gasifier technology is at present under commercial development in Finland, with a projected commissioning date of late 1982.

5.9.2 PRODUCT AND PRODUCTION METHODS

The fixed-bed co-current gasifier, which is described in detail in Part 4, is being developed by the Technical Research Centre of Finland. Of the many gasifier configurations which are possible, this one was chosen because of its relative simplicity, the capability of using the low-Btu gas product directly in a diesel or Otto engine, and the minimal staffing required for operation in small, remote communities.

Sod peat is fed to the gasifier with co-current injection of air. This configuration produces relatively clean gas which can be fed to an engine after it has been cooled to 30-50°C in a thermal recovery exchanger. The nature of the combustion process limits the size of the gasifier to less than 1 MW gas energy output.

It is possible to convert existing oil-fueled diesels to co-firing with low-Btu gas by replacing the cylinder head with one containing two sets of injectors per cylinder. The diesel engine which drives the electric generator requires about 10% of its energy input in the form of fuel oil. The conversion cost may be moderate (estimated to be 5% of engine replacement) to high, depending on the possibility of serial manufacture of conversion kits. For purposes of this analysis it is assumed that a new diesel generator set would be provided with the gasifier unit.

The gasifier being designed is based on modules of 400 kW electrical output/490 kW thermal output. Normally two modules would be provided in order to take advantage of the economies of a larger scale sod peat production operation.

The capital and operating costs for a two module operation are detailed in Table 5-12 and are based on costs developed by ORF, derived from Finnish data. The cost of sod peat of $49 per tonne is based on a judgement that the peat available in the location where the gasifier may be used will cost more than the estimate $35 for Northern Ontario but less than the $62 cost for the Hudson Bay Lowlands. The $60/bbl cost of fuel oil was obtained from Ontario Hydro, and is the cost of oil delivered by rail or road to remote communities. The $8/MM Btu credit for heat assumes that it will be possible to use the waste heat in a district heating system. If the cost of user generated heat were based on fuel oil at $60/bbl it would be much higher than $8/MM Btu.

TABLE 5-12. CAPITAL AND OPERATING COSTS FOR 2 x 890 kW[1] MODULES.

Capital Costs	
Investment	$ 1,335,000
Working Capital	26,700
	$ 1,361,700
Operation and Maintenance	
Raw Material	
Sod peat @ $49/tonne	$ 241,000
Diesel Fuel @ $60/bbl	131,800
Maintenance and lube oils @ 3.14 mills/kWh	33,500
Labour: 4 men @ $20,000/yr[2]	80,000
Net Operation and Maintenance	$ 486,300

[1] This 890 kW is a total of the 400 kW electrical and 490 kW of thermal power produced by one module.
[2] $20,000 per man year is used for isolated areas where a relatively simple unit operation is assumed.

TABLE 5-14. CALCULATION OF COST OF POWER FROM 2 MODULE PEAT GASIFIER.

	$
Annual Capital Charges (assuming 20 yr. life, 20% cost of capital)	279,700
Annual Operating & Maintenance Cost (from Table 5-11)	486,300
	766,000

Annual Output (electrical):
400 kw x 6000 h x 2 = 4,800,000 kWh

Credit for Heat Output:
490 kw_{th} for 6000 h @ $8/$10^6$ BTU x 2 = $160,600

Net cost of electrical output:

$$= \frac{766{,}000 - 160{,}600}{4{,}800{,}000 \text{ kWh}} = \textbf{12.6¢/kWh}$$

with thermal output credit at $4/$10^6$ BTU = **14.3¢/kWh**

5.9.3 POTENTIAL MARKETS

In Ontario there are several remote areas which are provided with electrical power by Ontario Hydro by means of diesel generators. There are approximately 1,000 domestic customers in total, in these remote areas, the annual electrical peak loads in some of the larger communities reaching 400 kW. The rates are based on proximity to rail and road transport for fuel oil with those communities only accessible by air paying a separate rate. In all cases a 20 amp, 220 volt service is provided at a significantly lower rate. The current schedule of rates is given in Table 5-13.

Some of these communities are located in northern areas of Ontario which have significant indicated peat reserves and are in climatic regions conducive to sod peat mining. In addition there is also a potential in specific communities for heating public buildings such as hospitals and schools with a central heat supply.

TABLE 5-13. ONTARIO 1981 RATES FOR ISOLATED SERVICE.

	¢/kWh
Restricted Use	
20 amp/220 volt service	9.25
Unrestricted Use	
if fuel delivered by air	40.5
if fuel delivered by road or rail	29.1

Source: Ontario Hydro.

It is expected that the level of electric power demand in these areas would increase substantially from their present low levels if a supply of relatively low-cost power were available. In the following analysis it has been assumed that demand has been limited by price and would gradually increase sufficiently to justify a larger generating capability than currently required.

A two module gasifier/generator plant would require approximately 5,000 tonnes per year of sod peat production, and would be restricted to geographical areas of Ontario which have 1) favourable production conditions; 2) no expectation of being connected to the provincial grid; 3) a current load of approximately 400 kW or greater. This suggests that the plant would have to be located in Northwestern Ontario.

The cost of power is estimated by summing the capital charges calculated at a nominal rate of 20% and the operating costs shown in Table 5-12 and dividing these by the number of kilowatt hours produced over a year (see Table 5-14 for calculations). This assumes that the facility would operate at a load factor of 68%. The cost of providing power is estimated to be 12.6 ¢/kWh, which compares favourably with the unrestricted rates of 29.1 ¢/kWh and 40.5 ¢/kWh. This is the primary market that the gasifier would be targetted for, with the restricted rate of 20 amps per customer forming a base load.

The estimated cost of 12.6 ¢/kWh assumes a credit for the thermal output of the gasifier at a low value relative to the actual cost of heating with fuel oil in remote communities. However, if it is assumed that wood fuel is the primary fuel that is displaced, the credit could be reduced to approximately half its original value. In this case the net cost of producing electric power is 14.3 ¢/kWh.

It is apparent that, based on the cost estimates available at this time and the preliminary information on isolated Northern communities, the gasifier/generator plant is a potential application for the use of sod peat to displace fuel oil. The possibility for the reduction of initial capital costs exists if the existing diesel generators could be converted to use the peat gas/oil mixture. The technology for this conversion exists and is currently being tested, but further information is required on the diesel engines presently operating in the remote communities before their suitability for this conversion can be estimated. Also, field investigations of the markets must be carried out.

5.10 PEAT COKE PRODUCTION FROM SOD PEAT

5.10.1 GENERAL

Under this scenario a large multi-product facility would be established to produce as a primary product, peat coke and as secondary products peat briquettes, electrical power and process heat. The analyses presented in this section are based on the use of the Outokumpu Peat Coking Process in the proposed facility. A commercial size plant using this process has been in operation by VAPO (state fuel centre) since 1976 at Peraseinajoki, Finland. Data obtained from Outokumpu on the capital and operating costs for the Peraseinajoki plant have been used.

5.10.2 THE PRODUCT AND PRODUCTION METHODS

The Paraseinajoki plant which uses the Outokumpu peat coking process uses 185,000 tonnes of sod peat at 35-45% moisture annually when operating 7,000 hours per year. Because of the quantities of peat used by the process the plant should be located as close as possible to a bog or group of bogs capable of supplying the required tonnage of

sod peat. The output of the plant is typically as shown below:

peat coke	30,000 tonnes/year
peat briquettes	30,000 tonnes/year
electric power	12 Megawatts
process heat	20 Megawatts

The proportions of electric power and process heat produced can be varied if necessary, to suit local conditions.

The Outokumpu peat coking process described in detail in Part 4 is summarized in the following paragraphs.

At the start of the process the fines contained in the peat sods are separated for use in the production of briquettes. The sods are then heated in a rotary dryer to reduce their moisture content to 10-15%. After the sods have been dried the fines are again separated. The fines obtained at these two points in the process are flash dried and compressed without any binding material, in briquetting presses. The sod peats at 10-15% moisture are then fed to a counter-current rotary kiln, where the coking process takes place at temperatures between 500 and 900°C. All heat used in the process is generated by burning gasses that are driven off during the coking process. Part of the heat generated by the process is recovered using a waste heat boiler. The recovered heat is used for electrical power generation and district heating (including greenhouses).

TABLE 5-15. UNIT COST OF PEAT COKE BASED ON OUTOKUMPU PLANT.

	$000
Capital charges	$ 6,900 annual
Operating — raw materials	6,500[1]
— labour (Staff of 100)	3,000
— maintenance	900
(3% of capital cost)	$17,300
Credits:	
electric power @ 2.57¢/kWh	(2,200)
thermal energy @ $8/MM BTU[2]	(3,100)
	$12,000
Cost per tonne of peat coke and briquettes	$ 200/tonne.
Assuming briquettes could be sold at $140/tonne on a wholesale basis (based on current prices in Finland):	
Total cost	$12,000
less: briquette sales	4,200
	$ 7,800
Revenue Required per Tonne of Peat Coke	$ 260/tonne

(1) Based on sod peat at $35/tonne. 185,230 tonnes/yr.
(2) After deducting 10% station usage.

The cost estimates used in this analysis are based on information received from Outokumpu in Finland with regard to the plant they are operating and have been updated by Outokumpu to indicate the current dollar cost of reproducing their plant in North America. No specific allowances have been made for possible cost differentials between Finland and Ontario. Operating costs have been estimated using an assumed Ontario labour cost and the manpower requirement specified by Outokumpu. All major utility requirements are assumed provided by the process. The cost of the sod peat used in the process is based on a Northwestern Ontario location for the plant with no allowance for transportation, i.e. with the plant at bogside. The resulting capital charges and operating costs are summarized in Table 5-15.

5.10.3 POTENTIAL MARKETS

The four products of the proposed facility specified above are coke, briquettes, electricity and thermal power.

The possible markets for the peat coke include the following industries, Smelting and Refining, Mining, Iron and Steel, Chemical Products as well as other small users. The production and disposition of coke in Ontario for the years 1978 and 1979 is listed in Table 5-16 with disposition detailed by end-use industry. The chemical and physical characteristics of peat coke differ from those of coal based coke. Peat coke generally has fewer chemical impurities than coal coke. Since these impurities are considered detrimental to various alloying processes and silicon production where coke is used, peat coke is preferable. Peat coke's compression strength is lower than that of coal based coke.

Several of the industries identified as present users of coal based coke were contacted to determine whether their specific coke applications would allow the substitution of peat coke on a commodity basis with virtually no process modification and thus no requirement for capital investment. As a result of these preliminary contacts it was determined that the major users, the steel makers, cannot use peat coke because of its low crushing strength. This leaves an estimated possible Ontario coke market in the order of 250,000 tonnes per year.

The iron mining industry's use of coke as a binder in the iron ore pelletizing process appears to be a viable application for peat coke, indeed peat coke is preferable due to its superior binding qualities over coal based coke.

As noted above, peat coke is not suitable for use by the largest coke user, the steel mills. It is, however, suitable for use in the iron mining industry and the chemical industry in various chemical processes that utilize the carbon contained in the coke. To determine the potential penetration of these markets by peat coke an estimate of the cost of peat coke has been developed.

The cost analysis is based on the cost estimates noted earlier and the product mix previously specified. The by-products of electric power and thermal energy have been taken as credits to the process at their estimated opportunity costs. The electric power credit has been calculated using Ontario Hydro's bulk power rate to distributing companies for 1981, at a voltage level of 230 kV and an annual load factor of 80%. The credit for thermal energy has been based on a district heating value of $8 per million Btu's.

TABLE 5-16. ONTARIO PRODUCTION AND DISPOSITION OF COKE 1978 AND 1979.

	1978		1979	
	'000 Tonnes	Tera-joules	'000 Tonnes	Tera-joules
Supply				
Production	4530.0	130,601	5122.1	147,671
Exports	6.7	192	67.4	1,944
Imports	206.8	5,961	97.1	2,800
Inter-region transfers	—	—	–60.3	–1,739
Adjustments	–147.7	–4,258	–48.9	–1,409
Stock variations	65.2	1,880	347.7	10,025
	4517.2	130,231	4694.9	135,354
Consumption				
Smelting & Refining	29.0	836	0.7	21
Mining	120.5	3,473	121.3	3,498
Iron & Steel	4179.6	120,499	4412.1	127,201
Chemical Products	34.9	1,007	34.4	992
Other manuf'g	153.2	4,416	126.3	3,642
	4517.2	130,231	4694.9	135,354

Source: Statistics Canada

For the calculation of annual carrying charges applicable to the total capital costs, it has been assumed that a rate of return of 20% per year would be required. A service life of 20 years for the peat facility is assumed.

Based on the above considerations the average cost per tonne for peat coke was calculated and is summarized in Table 5-15. It should be recognized that the revenue requirement per tonne of peat coke is highly sensitive to the assumed price of briquettes. The market for this by-product would need a thorough investigation.

The derived peat coke estimated revenue requirement of $260/tonne is approximately 85% greater than the current export market price for coal-based coke. This price differential indicates that peat coke is not now competitive for the alternative uses investigated. Other uses such as activated carbon could be considered as more detailed data becomes available.

5.11 SOD/MILLED PEAT PRODUCTION FOR USE IN DISTRICT HEATING

5.11.1 GENERAL

Under this scenario a district heating system using sod or milled peat as a fuel would be established to provide heat to consumers of large amounts of low temperature heat located in reasonable proximity to the district heating plant. If the plant is fired on sod peat, this scenario would allow for the sale of sod peat to individuals for space heating where their heating load is insufficient to justify connection to the district heating system. District heating is, in general, only viable in areas having high heat load densities.

5.11.2 THE PRODUCT AND PRODUCTION METHODS

The primary product under this scenario is heat in the form of hot water delivered to the user after being generated in a central facility. The hot water would be delivered to the user at a temperature of approximately 120°C and returned to the heating plant at a temperature of about 70°C (typical for Scandanavian systems). If the heat load is not very high due to high ambient temperatures the water flow can be reduced to maintain a reasonable temperature drop across the users heat exchanger. Water has been selected as the heat distribution medium rather than steam because of the lower line losses that occur when it is used. The lower line losses improve the system's efficiency for short distribution links and allows the district heating system to be extended over a larger area than otherwise possible.

The central heating plant can be small or large, as required by the demand identified. Plants ranging in size from 1 to 20 MW are presently being used with larger plants feasible if the demand for the heat exists. The plant would be designed to burn either sod or milled peat as its primary fuel and would be able to burn fuel oil or natural gas to supply secondary firing as required for startup and complete combustion purposes (smaller size units).

A district heating system such as that described briefly above has a number of advantages over distributed heating systems:

- a primary advantage is that the energy contained in the fuel is more efficiently converted to heat in a large, central, possibly automated boiler facility than in small distributed heating systems;
- a reduction of fuel handling costs (1 user vs many), thus reducing the total fuel cost;
- a district heating operation can justify the development of a dedicated mine operation;
- a district heating system can provide a basic distribution system and an operating organization that could collect and distribute industrial waste heat; and
- a reduction in emissions from the firing of a specified quantity of peat because the large furnace would be cleaner burning and because the installation of emission control equipment might be justifiable.

5.11.3 POTENTIAL MARKETS

The potential market for district heat is restricted by a number of simple considerations. The first is that the density of the heating load that the system is to service must be high to make the system economic. The second is that the cost of the piping to deliver heat to the final consumer is high, making the connection of small users (i.e. residences) to the system uneconomic. Thus, the potential market for heat from a district heating system is any area with a high heating load density and large users.

For purposes of this analysis, the sizes, modern apartments and hospitals that could be supplied with heat by a 1 MW district heating plant have been estimated, based on various available input data and are: 200 apartments[1]; or 56,000 square feet of hospital space[2].

Thus, a 200 unit apartment building could use 1 MW of heat from a district heating system which suggests that apartment complexes, often with hundreds of units would be potential users of heat produced by a district heating system. A 300 bed hospital located close to a 600 unit apartment complex would be able to utilize the heat from a 7.5 MW district heating plant.

The level of penetration of the markets identified that could be achieved by a district heating system is dependent on the relative costs of heat from the system and those incurred if the heat is generated by the user. The cost of user-generated heat includes the fuel cost estimated below and the capital charges and operating costs of the system.

The costs developed below for a 2.5 MW system are based on data obtained relative to the operation of the district heating plant for the town of Kannus in southwest Finland. The estimated capital cost of a plant like that at Kannus with a heat output of 2 MW when peat fired would be 3 million marks FOB Finland. This is equivalent to a levelized capital cost of $3.0/MM Btu of heat produced. The fuel consumption of such a plant would be approximately 10.6 tonnes of peat/day at a cost of $3.40 MM Btu's of heat produced. The operating costs for such a plant are estimated to be $2.2/MM Btu of heat produced. Thus, the total cost of the heat produced is $8.6/MM Btu. This compares with fuel costs of $8.7/MM Btu for fuel oil fired heaters, $9.0/MM Btu for electrical heat and $4.08/MM Btu for gas fired heaters. It should be noted that only the fuel portion of the total cost of user generated heat has been calculated here (assuming that existing facilities would be used). Inclusion of an allowance for capital charges and operating costs would raise the cost of user generated heat and thus show district heating to be more competitive.

This would suggest that district heating is competitive where electricity and/or fuel oil are being used for heating. Thus, medium size towns in northern Ontario should be considered as possible locations of a peat fired district heating system, if density levels are sufficient to warrant such a facility.

[1] Based on actual data obtained for a modern, well-insulated apartment building in Ottawa.

[2] Based on data for an existing hospital in Thunder Bay.

5.12 WET-MINED PEAT PRODUCTION CONVERTED TO A PEAT-DERIVED FUEL FOR POWER GENERATION

5.12.1 GENERAL

The scenario outlined below is based on the 'JP-Energy' method of upgrading the fuel value of wet-mined peat for application as fuel for a lignite-fired thermal generating station. An estimated cost per million Btu of producing a powdered peat derived fuel (PDF) in a plant adjacent to an existing power plant is developed and compared with the current, delivered, cost of lignite. Although this application may not be the only possibility for peat derived fuel, it is felt that it is a large scale use which the promoter of the 'JP-Energy' process has indicated as a possibility and was, therefore, selected for this study. Another application which was not investigated but which is in the demonstration stage in the United States is the substitution of powdered PDF for residual oil as boiler fuel. It is intended that the PDF be fired using the existing or slightly modified furnaces originally designed for oil or coal.

5.12.2 PRODUCT AND PRODUCTION METHODS

The 'JP-Energy' process is a large-scale peat refining process which considerably upgrades the heat value of the peat through a wet-carbonization reaction. The process has recently been developed by JP Energy Oy in Finland but utilizes equipment modules which are widely-used in the chemical process industry.

Peat at 80% moisture is removed from the drained bog and transported to the plant where it is diluted to 90% moisture, homogenized mechanically and heated to 200°C in a train of heat recovery exchangers. Then in the wet-carbonization reactor chemical changes take place which allow mechanical dewatering of the peat to about 50% moisture after having been cooled to 80°C. The wet-carbonized peat slurry is then flash dried to a final moisture content of 8-10%. The product can be provided in powder or pelletized form. The extensive provision of heat recovery equipment allows the plant to operate with a minimal utility input. All wastewater is biologically treated to pulpmill effluent standards and the flue gases are cleaned to acceptable composition.

The capital and operating costs are based on information supplied by JP-Energy Oy and Wheelabrator-Fry Inc. (developing the process in North America) for a 540,000 tonne per year operation. These costs have been scaled down by Ontario Research Foundation to represent a 200,000 tonne per year plant size. A summary of the costs is shown in Table 5-17.

TABLE 5-17. JP-ENERGY PROCESS CAPITAL AND OPERATING COSTS.

	$000
Capital	
Investment	$ 36,370
Working capital	727
	$ 37,097
Operating	
Raw material	$ 7,150
Operation & maintenance	2,700
	$ 9,850

5.12.3 POTENTIAL MARKETS

It is assumed for this analysis that one of the possible applications for this large scale wet-mining and carbonization production of peat derived fuel (PDF) is in the displacement of lignite fuel at a thermal power plant. In particular, the existing Ontario Hydro plant at Thunder Bay and the planned units at Atikokan could be considered in view of their location close to substantial peatlands. However, additional information on peat characteristics is required if further detailed evaluations are to be carried out. These plants are designed to burn Saskatchewan lignite as a primary fuel. This fuel is low in sulphur, as is the PDF, but has relatively higher ash content and lower heating value than PDF. The following is a comparison of the relevant characteristics (with PDF specifications from Finnish peat).

	Saskatchewan Lignite	PDF
Ash %	9	4.5
Sulphur %	0.4	0.2
Heating value Btu/lb	7,000	9,300

The current delivered cost to Ontario Hydro for Saskatchewan lignite at Thunder Bay is assumed to be $30/tonne. This is equivalent to $1.95/MM Btu. The higher heat content, lower ash and possibility of delivery to the thermal station in a powdered form makes PDF an attractive fuel from a physical characteristics viewpoint. However, the overall suitability would have to be determined through extensive testing.

The cost of supplying PDF to a thermal station is estimated to be $87.35/tonne or $3.92/MM Btu. This would indicate that a significant premium over the current lignite cost of $1.95/MM Btu would have to be justified by non-price factors.

It should be noted that the cost of PDF of $87.35/tonne is very rough and is based on very preliminary data. The wet-mining technology at the scale required is still not fully proved, and the costs of the PDF plant are based on engineering estimates and supplier quotations. Thus, the results presented above should be used with care and further study of this application of peat is required.

5.13 SUMMARY

In this Part, eight alternative applications of peat have been identified, defined in general terms and the ability of the products produced to compete in the market place with the competitive products identified has been evaluated at a preliminary level.

It should be noted that the analyses described in this part are designed to evaluate the potential of the alternative applications and should not be construed as a detailed investigation of the applications. For example, the cost of peat used in this part is a value typical for the province, i.e. Western Ontario, and the effect on the competitiveness of products produced by using the peat cost estimate for Southern Ontario (improve) or Northern Ontario (lower) has not been considered. The actual location of the bogs, the demand centres and the distance between them has not been specifically reviewed, rather a twenty mile haulage distance was assumed. In addition, for the price of the competitive fuels, typical values, that are not geographically specific, have been used in the analysis. Also, the following items have not been considered in this evaluation of the alternative application; handling constraints (real and imagined); environmental (air, ash); marketing programs including the education of the potential peat consumer.

It was determined that there exists in Ontario a market for the products produced for each application, however, some of the alternatives do not produce products which, at this time, are judged to be price competitive with the alternatives considered. Generally, those scenarios in which peat was used without significant upgrading were judged to be more competitive than those that involved significant upgrading of the peat.

With the above qualifications in mind, it is concluded that in the short-term, the following of the eight alternative applications investigated warrant more detailed investigation and the expenditure of effort aimed at commencing the utilization of Ontario's peat resources for the applications identified:

- Horticultural Peat Production for Agricultural Uses;
- Small Scale Sod Peat Production for Space Heating;
- Sod Peat Production for Residential and Non-Residential Space Heating;
- Sod Peat Production for Industrial Process Heat Generation;
- Sod/Milled Peat Production for Use in District Heating;
- Sod Peat Production for Power Generation using a Small Scale Peat Gasifier.

The other applications investigated, "Sod Peat Production for Coking" and "Wet Mined Peat Production Converted to a Peat Derived Fuel for Power Generation" are expected to become viable as the associated technologies are developed and as market niches that can be efficiently filled by the product of these processes are identified.

As noted previously the potential applications identified above as competitive have been selected by necessity on the basis of limited information. There are two general activities that can be undertaken to support the development of the applications identified related to improving the data base. The first is to conduct field investigations that would generate more detailed, possibly site specific data on potential consumption, peat resources and production costs. The second is to undertake a program to educate the potential consumer of the products identified, and measure their response to the information presented.

The applications identified above as warranting more detailed investigation each make use of peat in a different manner to serve different markets. Because of these differences, activities aimed at assisting the development of the peat resources of Ontario for the applications described is specific to the application considered.

In the discussion of the Horticultural Peat Production for Agricultural Uses, it was suggested that a horticultural peat mine producing 30,000 tonnes of bogged peat for the Ontario and export markets would be a viable operation. Reasons for the absence of such a plant at the present time may be due to one or more of the reasons discussed in section 5.5.3 particularly the timing of cash flows and the cost of identifying a suitable bog. There are a number of activities the province could undertake to increase the likelihood of the suggested mine being established. The first activity consists of carrying out a detailed evaluation of potential horticultural peat bogs in the province to provide potential investors with a better idea of the areas where detailed site investigations should be carried out. The second would be to assist the potential mine developer to procure capital by guaranteeing the loans made to the developer in the case of a bad harvest due to bad weather.

The discussion of the Small Scale Sod Peat Production for Space Heating suggested that such an application is viable in the rural areas of Ontario. It is not expected that this scenario will develop of its own accord for two reasons. The first is that the potential users are probably not aware of the potential that exists for them to mine and use peat and the second is that the cost evaluation of the suggested application is based on data extrapolation and not an analysis of an existing Ontario operation and is thus, subject to various significant uncertainties. The government could encourage the development of this application by educating the potential consumer and by assisting, possibly financially, in the establishment of one or more demonstration project(s) in the province.

The Sod Peat Production for Residential and Non-Residential Space Heating was judged to be viable, particularly for small communities in north-central Ontario. Reasons that this use might be slow to develop are that the potential consumer is probably not very aware of the resource and the use he could make of it and fuel peat is not presently mined and used in such an application in Ontario. The activity that the province could undertake to support the development of this application include, as above, the education of the potential user, and the establishment of one or more demonstration project(s) to prove the application's viability in Ontario.

The discussion of the Sod Peat Production for Industrial Process Heat Generation suggested that the pulp and paper and cement industries at plants in Kenora and Picton respectively have the greatest potential to utilize peat of the industries examined. The initiation of programs to educate the potential users identified about peat as an alternative fuel might be sufficient to cause them to carry out site specific studies. If not, a site specific study carried out by the government would probably lead to the development of the peat resource in the manner outlined for this application.

In the discussion of the application, Sod/Milled Peat Production for Use in District Heating, it was suggested that this application is cost competitive with user generated heat, on the basis of the preliminary figures reviewed. The competitiveness of the district heating application is expected to improve as the cost of alternate fuels increases more rapidly than the cost of peat. To support this alternative the province could carry out site studies to identify potential locations for a district heating plant. Once these locations had been identified it would be possible to carry out more detailed cost comparisons.

The discussion of Sod Peat Production for Power Generation using a Small Scale Peat Gasifier suggested that several northern towns are potential users of peat in this application. The factors limiting the likelihood of this application being developed include the apparent lack of a sufficient demand (excluding demand presently price limited) and the fact that the technology is not fully proven. To assist in the development of this application the province could investigate the demand that can be expected if general purpose electrical rates are lowered in the potential markets identified and monitor the technology, especially with reference to the potential for the existing diesel generators to be converted to peat gas firing, reducing the cost of power produced.

PART 6
Environmental Considerations

6.1 GENERAL

Until recently most of the work dealing with peatland utilization and its effect on the environment has concentrated on the effect that draining of peatland has on the groundwater table. This aspect has been studied in great detail, especially by European foresters in connection with the drainage of peatland for forestry. Recently, the possibly harmful physicochemical effect of drainage, habitat changes, medical effect of peat dust on workers, possible air pollution by peat-fired utilities and environmentally acceptable reclamation procedures for mined-out peatland areas have been subjects of research.

Conventional peatland utilization processes can be divided into 3 phases: pre-production, production, and post-production. Each of these phases may have slightly different environmental impacts and will be discussed in brief separately.

6.2 PRE-PRODUCTION PHASE

The pre-production phase involves land clearing and bog preparation activities such as tree removal, surface preparation and drainage as shown on Plate 6-1.

6.2.1 LAND CLEARING

The major visual effect of peatland utilization is the clearing of the bog surface of all the vegetation. Some of the clearing also extends to the adjacent mineral terrain to meet the needs of possible plant facilities, access roads, and stockpile areas for mined peat. Commonly, the areal extent of the units of peatland taken into use to support conventional production practice ranges from 50 ha to several thousand ha, corresponding to about 10,000 tonnes/year to several hundred thousand tonnes/year of milled peat production respectively.

Land clearing on the bog involves the removal of trees, chopping and cutting of the shrubs and rotovating the surface peat. In some cases, the surface peat may be removed to expose strongly humified peat layers. These preparation activities are similar to those used for agricultural lands.

Tree removal is usually done by pulling the trees with a tractor. The trees are then hauled off the bog and chipped if they are large enough or otherwise they can be burned if there is no other use. The lower surface vegetation (shrubs and smaller trees) can be chopped or cut with a bush cutter. Then, the first 5-20 cm of the surface peat is usually mulched with a rotovator. The initial layer of chopped and mulched material can be left on the bog or removed and used as a soil conditioner. Before starting peat production, the fields are contoured with equipment such as a screw profiler to improve surface water runoff.

This kind of land clearing obviously changes the peatland character. However, the environmental impact caused by land clearing is local and limited mostly to the site. The parts of the deposit planned for use are, biologically speaking, quite inactive* and the effect of the drainage on the habitat to be minor. The edges of the bog (a more biologically productive area of the peatland) are generally left untouched except at points where a service or an access road has to be built, thus, leaving the edges in their natural state. The clearing process can be compared to that carried out when land is cleared for farming, and the environmental effects should be similar or less.

6.2.2 LAND DRAINAGE

The most important, and perhaps most environmentally significant, activity in developing a bog for commercial use is the drainage of the peatland area. The in situ moisture content of peat varies from 85-95% (on a wet weight basis) depending on local conditions. A peatland at such a moisture content cannot carry bog production equipment nor is it possible to use conventional mining methods to recover peat from an unprepared wet bog. To achieve conditions where dry mining can be carried out, the bog has to be drained. The aim of drainage is to lower the water content of the upper layer sufficiently to make the surface firm enough to carry production equipment. This is achieved by cutting a perimeter ditch around the bog to intercept water running from the surrounding terrain onto the bog, and as well to collect water from the field ditches.

The perimeter ditch is usually cut at the interface of the bog and the mineral terrain. The ditch may reach into the mineral soil water table in the case where it has to be cut deep enough to collect the water from a low-lying flat bog. In most cases, the perimeter ditch is about 1-1.5 m deep and a maximum 1.5-2 m wide.

The main body of the bog is drained by a network of field ditches. Commonly a 20 m ditch spacing is used. The ditches are deep enough to draw down the bog water table near the ditch about 60-90 cm from surface. This is achieved by ditches with a usual maximum depth of 1-1.3 m. Due to the high water retention of peat (e.g. sphagnum peat up to 30 times its dry weight) the water table is drawn down only about 20-30 cm in the center of the field.

The perimeter ditch can be cut either with a suitable excavator, and/or rotary or screw ditcher. The latter are commonly used for field ditches and are powered by a standard 4-wheel drive farm tractor.

When evaluating the potential environmental impact of draining a peat bog, there are a number of items that should be considered, such as local hydrogeology and groundwater conditions, drainage rates from the peat, the radius of influence of the lowered water table, and quality of the drained water.

In Finland an extensive drainage program for forestry purposes was initiated about 20 years ago and of the estimated 10 million ha of peatland in the country, approximately 5.5 million have now been ditched to stimulate forest growth. It is apparently not clear what the effects have been of draining such large areas but it is reported that there is a higher incidence of spring floods in the western coastal areas. However, the flooding in these regions may be caused by dredging of the upper reaches of rivers flowing into the sea in the west.

* The reader is referred to Part 2 where the distinction is made between peatland and wetlands (such as marshes, swamps, some fens, etc.) which are biologically more productive areas.

PLATE 6-1. VIRGIN PEATLAND AND PEATLAND DRAINAGE DITCH.

6.2.2.1 GROUNDWATER CONDITIONS

The mere existence of a peat deposit is an indication of a high groundwater table, either locally or regionally. The reasons for this are varied and include poor drainage, impervious soil types and a high water surplus. These are all factors involved in the formation of a peatland, in addition to other factors not pertinent in the present context.

A peat deposit has a groundwater system which may be directly connected to the general groundwater table, or it may have a perched groundwater table. The latter is a common feature of deposits where less humified peats are underlain by highly humified impervious peats, and where the deposit is located on a flat or sloping surface, rather than in a depression. In these cases, the drainage of the bog would affect only the deposit itself without interferring with the surrounding terrain or its water table.

In the cases where the bog water table is part of the general water table of the adjacent terrain, a slight lowering of the level might occur. However, the drainage ditches are not excessively deep (usually from 1-2 m), since the aim is not to achieve maximum possible lowering of the water table. In fact, the optimum condition is to lower the water table near the ditches 60 to 90 cm at the most.

Additional lowering of the water table may reduce the bearing capacity, under certain conditions, and can also hamper the milling operations by allowing too thick a layer of surface peat to be broken down by the production machinery. With highly humified sedge peats, too dry a surface layer can also reduce the sodding capability of the peat.

The only visible effect of bog drainage is in the bog itself and in a narrow zone outside the perimeter ditch where increased aeration, through increased drainage, usually improves the growing conditions for vegetation.

Where peatlands are very low-lying, the adjacent mineral terrain is often waterlogged by a high groundwater table. Under these conditions, drainage of the bog lowers the water table of the surrounding terrain. This is not expected to create environmental problems, except in areas which should have been left waterlogged for conservation purposes. Otherwise, drainage is expected to be beneficial, since it allows improved forest growth and the use of the land for agriculture.

It is often said that peatlands act as water reservoirs and dampers against flooding. Generally, in areas where peatlands abound, there is no shortage of water, but rather there is a surplus. Usually peatlands are, and remain, saturated throughout the year without releasing much water even during the occasional dry period. This is due to the inherent water absorbing and holding capacity of most peats. Also, in cases where the surface peats become dry, recharge from the more humified, lower peat layers is generally very slow since the permeability of humified peats is close to that of some clays (Korpijaakko and Radforth, 1974).

A natural peatland may not have real significance in acting as a damper against floods since sudden rainfall runs quickly as surface runoff over the already saturated peat without being absorbed by it. In drained peatlands, there should be a possibility of absorbing some water from a sudden rainfall.

The quantity of water "lost" by drainage is negligible. About one year after the initiation of drainage, the water table will be established at its new level. Usually this is about 30 cm, on average, below the old level. The "loss" occurs once, during initial drainage, since the water table will not sink further than the pre-determined depth.

6.2.2.2 INFLUENCE OF A LOWERED WATER TABLE

The drainage of a peatland affects only the general hydrological conditions of the immediate surroundings of the deposit. In Europe, where peatlands have been drained for forestry, it has been found that 50 metres away from the ditches no drainage effect is noticeable. Beyond the boundaries of the bog a lowering of the water table has been determined to result in changes in the biological productivity of the surrounding land (Petrov, 1980). However, in the case of waterlogged conditions, the sympton of which is an occurrence of peatland, a change in the biological productivity in the surroundings might be expected to be an improvement. This is because peatlands most suitable for peat production (i.e. thick deposits excluding marshes, some fens and swamps) are by nature relatively inactive biologically in comparision with e.g. forested land, a fact which is reflected in the accumulation of organic matter rather than in its degradation. In biologically highly active sites, the rate of accumulation is lower than the rate of degradation due to high microbical activity. The improved drainage is expected to enhance growth of vegetation at the edges of the peatlands creating habitats more suitable both to mammals and avian fauna.

6.2.2.3 WATER QUALITY

Most peatlands are quite acid. Typically the pH of ombrotrophic sphagnum bogs varies between 3 and 4.5, while in the more eutrophic peatland areas it is commonly between 4 and 5 and occasionally in limestone areas, may even be neutral (7). The low pH values are caused by the weak, well-buffered acids present in peat. Because the acids are weak, their effect on fish is insignificant should the bog water be discharged into fish habitats. Research has shown that under normal conditions, the acid bog waters appear to have no harmful effect on, for example, Salmonidae fish or on their spawning efficiency. However, in areas where the peatlands have been drained, a small short-term increase in acidity in the adjacent streams has been noticed after heavy rains. In regions where recent acid rains have created ecological problems, there have been indications that the drainage of bogs and the uncontrolled release of bog waters may have aggravated the situation.

A recent study of peatland drainage in Minnesota (Clausen, 1979), reported that drainage water from disturbed peat contained elevated levels of ammonia, organic and total nitrogen, total phosphorous, aluminum, iron, suspended sediment and colour. Alkalinity, specific conductance, pH, dissolved oxygen, magnesium, calcium and manganese were found to vary seasonally. Due to the variability of bog composition, the impact on the environment discharging bog water into streams adjacent to the bog will be varied. Only through hydrochemical analysis can the impact be measured. In general, European evaluations of bog water discharging have found no overly adverse effects to occur.

To perform the hydrochemical analysis of bog water, samples should be collected from shallow (say 1 metre) holes in the peat and at the outlet of the existing ditch system once the water table has reached a more or less steady state. Samples of the drainage water should be collected and analysed for temperature, colour, pH, specific conductance, acidity, alkalinity, total suspended solids, volatile suspended solids, dissolved oxygen, biological oxygen demand, total phosphorous, nitrogen species (total Kjeldahl, ammonia, nitrate, and nitrite), iron, manganese, aluminum, and zinc. A full scan of heavy metals should also be done on one or two samples collected. Similarly, water samples ought to be taken from the receiving water to obtain its characteristics.

Water samples should be collected for analysis on a weekly basis for the first several months of the pre-production drainage, with additional samples being collected after major rainfall events. After the range of drainage water quality parameters has been established, the frequency of sampling could be reduced to about once every two months during the months when drainage is occuring. It should also be possible to substantially reduce the list of analytical parameters after it is determined which parameters are most significant. It is important however, to continue the sampling, even at a reduced frequency for at least one annual cycle. In a study of surface water and groundwater interactions in peat deposits in Alberta (Schwartz, 1981), significant seasonal fluctuations in water quality in surface runoff and streamflow were found.

Finally, a weir should be installed so that an indication of the volume of bog water being discharged can be obtained. Various mitigative measures can be taken in case volumes and quality of water discharged are not satisfactory. Some of the possible methods are described in Section 6.3.2.

6.3 PRODUCTION PHASE

6.3.1 DRAINAGE

With commencement of drainage activities in the bog preparation (pre-production) phase it is expected that only initially, increased quantities of water will flow at relatively high rates of flow from the newly opened or cleared ditches. Usually the flow rate subsides within a few days, however, during this phase some loose peat can be washed out. This will decrease by the time peat production is ready to commence. At this time, the water table in the drained area will have been established at the desired depth from surface. The release of extra water annually as mining progresses is insignificant. The quantity of drainage is expected to decrease over the years because the area of drainage influence will slowly decrease as the usable mining area diminishes.

During periods of low rainfall, the flow in the ditches will be minimal and may, during periods of drought, cease entirely for a few days. This is due to the high water holding capacity of peat. In most cases, large and rapid water flows during the production phase will only occur in the spring during the spring runoff and possibly later after heavy rains.

The spring runoff commonly takes place while the bog is still frozen and thus, no special effect should be noticed. Later during the summer, a temporary increase in the runoff occurs after rains. At these times, the pH of the adjacent stream may be lowered briefly and very locally.

6.3.2 SILTING

Depending on the mining method, varying quantities of fine peat can be transported by the drainage ditches from the bog to the surrounding waters. Research has shown that in the areas of older peat operations, the peat silt transport (under normal conditions) does not appear to be significant (Korpijaakko and Pheeney, 1976). However, newly opened drains full of water, can carry large quantities of peat particles into surrounding waters for a short time period. This may cause some short-term ecological damage. It is possible this could occur during the winter when the decay of the additional organic matter in the receiving waters could cause a deficiency of oxygen under the ice. Imposing an increased organic loading on small, shallow lakes could result in eutrophication of the lake. The resultant heavy growth of aquatic vegetation might render the lake undesirable for swimming and boating. Low oxygen levels resulting from decomposition of peat fines might result in fish kills and the peat fines may also damage the spawning grounds of various fish species.

It should be noted that silting would be more severe when using the milled peat mining method, versus the sod peat method where fine peat is created only in negligible quantities.

Depending on local conditions, it may be advisable to minimize the transport of peat silt by using holding ponds which allow the silt to settle and release water of improved quality. Alternatively, the drainage ditches can be terminated in suitable flat areas leaving a buffer zone of undisturbed peat between the drains and the receiving waters, allowing the water to slowly seep into the natural channels and the peat fines to be filtered out. The ensuing terrestrial effect can be designed to be very localized without extensive effect on the surroundings.

6.3.3 HABITAT CHANGE

The most conspicuous impact a peat mining operation has on environment is to change the nature of the deposit being mined. Draining, subsequent stripping of vegetation and slow removal of peat changes the peatland habitat by a natural one to a cultural one in a manner similar to converting land to agriculture. The change of peatland habitat is total and nothing of the old habitat, except the peat deposit, is left. This change may appear objectionable from the point of view of preserving the original landform. However, from the point of view of land use, it can be beneficial (see Plate 6-2).

In a biological sense, a typical Canadian peatland with thick peat layers (1 m or more) and open vegetation is quite unproductive in comparison with e.g. forested land. It offers a living habitat to relatively small populations of animals in comparison to the mineral terrain with a varying vegetal cover. Parts of the peatlands can be biologically productive, for example, the edges of the bogs and the shallow eutrophic peatlands. However, these areas are not developed for peat mining because of shallowness of peat (1 m or less) and do not suffer from the peat mining operations. The drainage of the peatland proper, actually can enhance the growth of vegetation near, and at its edges, creating habitats that may be more suitable e.g. for deer and moose, than previously.

At present, a very small fraction of Ontario peatlands have been taken into use, and there is no danger of obliterating this unique habitat by peat mining operations. Also a number of national and provincial parks contain large representative peatland areas conserved and protected from exploitation. The IBP (International Biological Program) project Telma is compiling a list of Canadian peatlands with unique features to be protected from use, ensuring the natural peatland areas will be left untouched.

6.3.4 PEAT DUST

6.3.4.1 NUISANCE

In milled peat operations, up to 10% of the daily production volume can occasionally be carried away by very strong winds. A heavy dust can cause nuisance in nearby towns and villages. However, most peat operations are remote from the larger population centers, minimizing the nuisance from airborne peat dust.

As this loss is also an economic loss to the operation, it is to the operator's advantage to minimize it. Proper mine planning, drainage and storage methods, taking into consid-

PLATE 6-2. RIDGE PEAT OPERATIONS IN NEW BRUNSWICK (TOP) AND FINLAND (BOTTOM).

eration the direction of the prevailing winds can help considerably in reducing wind loss and consequent nuisance to local inhabitants. The negligible quantities of fines produced in sod peat operations ensure a very low level of nuisance dust caused by peat operations.

6.3.4.2 MEDICAL EFFECT OF PEAT DUST

Until recently, almost no attention was paid to the possible health hazards of peat dust. Apart from eye and nose irritation, it was believed that peat dust caused no other problems. Recently, studies have shown that exposure to peat dust (in high concentrations at the work site) may be the cause of a number of respiratory and skin ailments (Ruhimaki *et al.* 1980). Research has not been done yet to establish the levels at which peat dust in the immediate vicinity of a peat mining operation may be hazardous.

6.3.4.3 EFFECT ON ADJACENT ENVIRONMENT

The addition of organic matter to the immediate environment surrounding the bog, as windborne peat dust, is usually of a very diluted nature. At the edges of the bog there are sometimes greater quantities of peat dust covering the ground, up to a few centimetres. The denser vegetation on the mineral terrain filters out most of the peat dust within the first few hundred feet of the bog. Particles flying higher with the wind may be carried varying distances. In most cases, it will be distributed over such large areas that the influence on the ecological balance is negligible. In many cases, the mineral soil is poor in organic matter and this small added quantity of material is welcomed and the settled peat dust may act as a soil conditioner.

6.3.5 FIRE HAZARD

Charcoal layers in peat indicate that periodically fires have occured naturally during the development of peatland (over last 10,000-12,000 years). The frequency varies depending on climatic conditions and recent activities of man. However, in recent fires, most occur due to man's inattention. Prepared peatland is vulnerable to fire, however, with protection equipment, fires are more easily controlled than naturally occurring fires.

The danger of fire on prepared peatland is elevated at certain times of the year, especially if peat is being collected by the milled method. Experience (e.g. New Brunswick) shows that fires are generally limited to the prepared part of the bog and can be prevented from spreading to the surrounding lands. The ditching network acts as a fire barrier (e.g. perimeter and field ditches). Peat operators often impose stringent fire regulations such as non-smoking pledges on the part of employees with the penalty of dismissal for violations. Insurance companies often refuse to insure operators without the assurance of no-smoking regulations enforced at the bog operations. A number of other precautions are also taken at bog operations and can include:

- fire-fighting equipment on hand e.g. poles and pails and shovels every few hundred metres, 2,000-3,000 feet of fire hose, portable fire pump and signs on the site,
- tractors equipped with various types of extinguishers (water & chemical), and a main fire wagon available such as a 1,000 gallon tanker, hose and motorized pump,
- hot exhaust gases vented upwards from bog vehicles, no gasoline engine equipment allowed to be driven on the bog,
- avoidance of harvesting milled peat during windy conditions, and
- leaving certain undrained ponds as water reservoirs.

Monitoring of stockpiles for avoidance of spontaneous combustion was discussed earlier in Part 3. Selective mining of hot spots and opening of the pile and applying water can prevent fires. Other measures include compaction of the pile to expel air, maintaining a least optimum moisture content for bacterial activity (e.g. 30-50% moisture) and, if possible, the ambient air temperature should be kept low, e.g. outside storage of peat.

6.4 POST-PRODUCTION PHASE

6.4.1 GENERAL

The post-production phase of a peat operation will occur after about 10-30 years of operating life depending on the production rate and the thickness of peat. Consequently, the final land use should be considered during the planning phases of the mining operations. There are several options for final land use. These include: reclamation of the area for agriculture, for silviculture, for recreational use, or alternatively letting it revert back to its original state.

The following is a brief description of common European practices on abandoned peatlands and a simplified suggested guideline which has been considered for an Ontario situation concerning the state of abandoned peatlands and how they should be left to facilitate future use.

6.4.2 RECLAMATION GUIDELINES

This guideline is based on the assumption that most peatlands can, and eventually will, be used for one or several purposes in the future and therefore should be left in a state that will enable subsequent use without extensive preparations. However, until the Province carries out a program of detailed peatland surveys and inventories only a generalized outline can be suggested. Ideally, of course, each individual peat development should be considered based on a comprehensive land use plan. It is expected this will be the case in the future, once more detailed information of the peatland types has been collected by the Province.

The method suggested here is based on experience elsewhere in the rehabilitation of peatlands as well as on the observation that the drainage of utilized peatland has to be carefully controlled to avoid the relatively quick degradation of peat that may take place if the peat is drained too thoroughly. To keep the peat in its natural state, post-exploitative drainage has to be carefully controlled within the framework of a generalized plan until the subsequent use is known and a more detailed plan can be implemented.

Almost any use of a peatland requires drainage. Therefore, to reclaim a peatland for a possible subsequent use after the primary exploitation has been completed, all the existing drainage channels should be left in good repair. They should also be supplied with control gates and weirs at suitable locations to permit the control of drainage and control of the groundwater table so that it remains about 20-25 cm below the surface. This is done to ensure a minimal rate of humification of the peat, while at the same time, the bog surface can be kept drained well enough to hinder a progressive paludification and to keep the surface fit enough to carry machinery that may be required for the possible use of the bog.

To ensure the best surface conditions for future use, the surface should be left as smooth as possible and with a suitable gradient so that water can run slowly into the adjacent drainage system without forming stagnant pools. For this purpose, the surface of the bog between the ditches has to be graded and planed. Experience has shown

that without planing and grading, even a bog with a dense network of internal drains does not drain well enough to suit certain uses (such as pasture land).

To achieve a proper rate of flow, the areas between the ditches should be graded so that the cross-fall will be about 1-2% and the longitudinal slope about 0.3%. The grading can be carried out either by bulldozers or screw levellers.

6.4.3 FINAL LAND USE

As is well known, peat is an excellent growing medium and a soil conditioner. Contrary to common belief, only 5-10% of peatlands originate in depressions formerly filled by lakes or ponds, in most cases the land after peat has been removed is flat. Commonly about 0.3-1.0 m of the bottom layer of peat is left in place and forms an excellent basis for either agriculture and forestry.

For agricultural purposes, the existing ditching should be maintained. Depending on the peat type, a number of systems and agricultural products can be considered. In areas with sandy subsoil and thin layers of peat remaining, a deep ploughing program can be applied. This method mixes the peat with the underlying sand and is commonly used in Germany (e.g. Sand-mischung).

In areas with deeper peat layers remaining, a proper drainage and fertilization program is needed. Some of the most profitable products are vegetables grown by utilizing intensive agricultural practices in contrast to the extensive practice used in the Prairies for growing grain. A Canadian example of intensive vegetable gardening on a peatland is the Holland Marsh in Ontario. A widespread use of abandoned peatlands in Europe is for grazing. In this case mole drains can be installed in the peat.

Peatland forestry is an old and well researched practice in Scandinavia, Germany and the U.S.S.R. Abandoned peatlands are well suited for forestry. Only a few large field drains are needed and they should be left shallow to avoid excessive draining of the land. Simple fertilization, such as broadcasting wood ash, can produce dramatic results in tree growth. Reclaimed peatland forest areas are well suited for mechanical harvesting because of their flatness and lack of obstacles such as boulders, etc.

In some areas, where frequent ponding occurs, abandoned peat mining areas can be left to revert to their original state, or turned into recreational parks for both wildlife and human use. Whatever the final use, it should be considered on a case by case basis.

6.5 ENVIRONMENTAL ASPECTS OF PEAT PROCESSING AND UTILIZATION

6.5.1 GENERAL

Although the previous discussion has centred around the environmental impact of developing a peat bog for fuel peat production, the impact of processing raw peat into various useful solid, liquid, and gaseous fuels and the impact of utilizing these peat-derived fuels must also be evaluated.

6.5.2 PEAT PROCESSING

Environmental considerations related to peat processing are discussed in some detail in Part 4 of the report. In processing peat to produce solid peat fuels (sods, milled peat, and briquets) few harmful by-products result. Little wastewater is discharged, however, some open air handling of peat can be expected to cause dust emissions. Air emissions and solid waste will be generated from fossil-fuel-fired boilers and dryers.

However large-scale wet carbonization plants can produce large quantities of wastewater; the amounts and treatability are unknown at this time. Small-scale gasification for operation of diesel generators to produce electricity can be expected to produce only diesel exhaust emissions and waste heat. Large scale peat gasifiers under development are expected to meet the required air and wastewater emission standards (e.g. U.S.). Details on the environmental concerns related to the various peat processes are not readily available since much of the technology is in early stages of development.

6.5.3 UTILIZATION OF PEAT-DERIVED FUELS

There are two main areas at present of utilization of peat-derived fuels. These are, domestic heating and thermal generation of electricity, process steam and district heat.

6.5.3.1 DOMESTIC HEATING

Briquettes and sods are currently used to heat domestic structures. As a rule, peat is a clean-burning fuel compared with some oils and most coals. Consequently, the use of peat as a fuel in a small domestic furnace is not expected to create environmental problems, more possibly a nuisance problem due to possible objectionable odours if the volatiles are incompletely burned (peat commonly contains 60-70% volatile matter).

One of the most undesirable pollutants in fuels is sulphur. Fortunately, peat commonly has a sulphur content of 0.1 to 0.3% (of dry matter) and therefore no unpleasant sulphurous odours are detected when burning. Although mercury can be found in peat, in comparison with other fossil fuels, the levels in peat are very low and consequently pose no known threat to domestic users of peat.

6.5.3.2 THERMAL ELECTRIC POWER GENERATION

In the thermal generation of electricity, milled peat is usually used, however, there are some instances where sod peat is being used. The utilization of peat is not expected to create undue environmental problems. However, possible areas of concern are the composition of the flue gas, the disposal of ash, and the control of fugitive emissions of particulates.

Flue gas from the combustion of peat consists primarily of carbon dioxide, water vapour, and nitrogen oxides in addition to excess air. The sulphur content of peat is low and so are the emissions. Some concern over the emission of nitrogen oxides is warranted since these gases have been linked to the acid rain problem being experienced in Ontario.

Although the ash content of peat is low, over the course of a year's operation large amounts can accumulate. A major concern over peat ash (both bottom and fly ash) is localized dust formation.

It can be expected that levels of suspended particulate matter in the air will increase with proximity to the plant site due primarily to fugitive emissions of particulates resulting from industrial activity, associated with construction and operation of the plant and from the handling of peat and peat ash. Emissions of particulates due to the handling of peat can be minimized by ensuring the enclosure of dump stations, storage bunkers and conveyor systems.

There are other environmental impacts to be considered when examining a thermal generating station, such as dispersion of flue gases, waste discharge of heat and noise, however, the factors discussed above are more particular to peat being used as the fuel.

6.6 SUMMARY OF ENVIRONMENTAL CONSIDERATIONS

The basic environmental concerns discussed indicate that, with existing technology (and some developing peat technology), peatland development is not expected to cause severe or significant impact on the environment, however, experience in this area is still lacking. The large peatland areas in Ontario are virtually unused and to alleviate environmental concerns requires careful research programs and monitoring systems (including background measurements) including a well planned system of guidelines and regulations to ensure the wise and orderly development of peatland.

One of the first steps in peatland development is an inventory program to identify and quantify the deposits and to rank them according to best suited end use. The ranking could include items such as environmental sensitivity, wildlife and conservation use, agriculture, forestry, recreation as well as peat mining. It is expected the vast majority of peatland will never be required for exploitations even with extensive development of an Ontario peat industry.

PART 7
Regulatory Guidelines

7.1 INTRODUCTION

To date, the commerical use of peat and peatlands in Canada has been rather small in scale and has not posed a significant environmental or land use problem. The recent growing interest in large-scale uses of peat as a source of energy has aroused public awareness of the possible environmental effects that large-scale drainage programs may have. Since large areas of peatland are on Crown land, the question of proper use of this public natural resource has arisen. In these contexts, the lack of efficient regulations to ensure proper land use concerning peatlands is evident. The situation appears to be common to both Canada and the U.S.A. Attempts to remedy the situation have been made, most notably in Minnesota and New Brunswick.

Since Ontario has some of the largest peat resources in North America, it is timely to start formulating regulations immediately to govern the use of peat and peatland and to ensure that no serious impact on the environment is caused and that the people of Ontario obtain proper benefits from the use of their resources. Part 7 is included to assist in the formulation of guidelines and regulations and it is not intended to influence policy, although it is difficult to avoid some assumptions on policy when commenting on aspects of guidelines and regulations for peat development.

7.2 REGULATORY AGENCY

7.2.1 EXAMPLES OF AGENCIES

In the Province of New Brunswick, peat (both energy and horticultural) is considered to be a quarriable substance and thus dealt with under the Quarriable Substances Act. The rights to the "quarriable substance are rested in the owner of the land in or on which they lie". According to this management policy, the peat on the Crown land is under the jurisdiction of the Mineral Resources Branch of the Department of Natural Resources of the Province of New Brunswick. Aspects of developing peat and peatland and occasionally leading into regulations have been dealt with by an inter-departmental committee.

In the State of Minnesota peat and peatland management policy has been formulated by the Department of Natural Resources with the assistance of two program advisory groups, the Peat Advisory Committee, comprised of legislators, industry representatives, local government officials and citizens and the Interagency Peat Task Force consisting of representatives from state agencies, the University of Minnesota and the Upper Great Lakes Regional Commission. Emphasis is placed on intergovernmental cooperation among the federal, state and local units to ensure uniform guidelines. The management responsibility is with the Department of Natural Resources.

7.3 ADMINISTRATION

In Ontario, peat is considered under two categories: energy uses and non-energy uses. These two groups are administered under one jurisdiction: the Ministry of Natural Resources. The disposition of the resource is the responsibility of the Land Management Branch, who administer that part of the Mining Act covering peat as a fuel source. That part of the Public Lands Act covering peat moss for horticultural purposes and managerial policy in relation to peat and peatlands is done by the Ministry of Natural Resources in cooperation with other Ministries and outside expert help.

The Ministry of Natural Resources is at present the final controlling administrator of the policies and regulations. Its disposition of peat, like all other natural resources, is subject to the Environmental Assessment Act (E.A. Act), 1975.

At present, the Act does not apply to private sector. Local governments owning peatlands are currently not subject to the E.A. Act, 1975. The Federal Government should have proper plans for the development of peatlands they own and of course will be subject to the Environmental Assessment Review process.

7.4 SUGGESTED REGULATORY PROCEDURE

7.4.1 OBJECTIVES OF PROCEDURE

The suggested procedure is intended to achieve the following principal objectives:

- to ensure a maximum and the most sound, both economically and environmentally, mode of utilization of publicly owned peatlands,
- to ensure that by instituting a proper level of fees, the privately owned peatlands also become economically attractive for utilization,
- to ensure minimization of land speculation,
- to ensure a properly planned multi-use of the land, and
- to ensure that all peatlands are developed in an environmentally acceptable manner.

7.4.2 ELIGIBILITY TO USE CROWN-OWNED PEATLAND

In order to be eligible to apply for any license to use Crown-owned peatland, the applicant should show proof of financial capability of being able to carry out the work required under each license, and to present a plan for development and production.

7.4.3 EXPLORATION LICENSE

Before the applicant is granted a lease he will have to fulfill the conditions of a peatland exploration license. The exploration license conditions could follow along the main lines as they exist at present in e.g. New Brunswick. Such a license would be renewable after a specified number of years. In New Brunswick this is three years. However, this ties up the land for a long time period. If the maximum area covered by the exploration license is set at 800 ha as in New Brunswick, there is no need to grant it for more than one year to allow the applicant to carry out the required work.

The exploration license would only be granted if the applicant was eligible as outlined in Section 7.4.2. According to New Brunswick regulations, the applicant cannot have other exploration licenses. He also has to propose a use that will not jeopardize the availability of peat to a possible existing leaseholder on the same deposit or one nearby. The exploration license holder has to show evidence of a certain annual level of expenditure to survey the deposit. This amount can be determined later.

The New Brunswick regulations limit the exploration license to a 800 ha unit or smaller. However, this area limitation should be flexible so that if a license is applied for a large-scale individual deposit, it should be granted as long as the applicant will be able to show that he can produce a detailed survey plan of the deposit within a year. Also, if there are a number of smaller deposits which together form a unit larger than e.g. 800 ha, the license should be granted to cover them all.

However, the applicant should also have a plan showing that there is a need for such a large area and that he is capable both financially and technically to develop it. This plan should show an accurate outline for the exploration license.

The successful applicant should be required to carry out a Level 3 (Table 2-16) survey of the bog. The results of the survey should be submitted to the Ministry of Natural Resources together with the analysis showing the suitability of the deposit for the suggested use. In case a lease is granted this data will be kept confidential for a number of years. How many, depends on final policy decisions.

There should also be a suitable fee levied for obtaining an exploration license.

7.4.4 PEAT PRODUCTION LEASE

In order to qualify for a lease, the exploration license holder should be required to fulfill all the requirements as described above. The application should be subject to a fee and the survey information should include:

- survey of the boundary of the area for proposed lease,
- profiles and maps of the bog with peat types and degree of humification, peat thickness, surface elevation and condition of the underlying mineral terrain,
- a drainage plan for the suggested operation,
- a mining plan and method,
- a plan for future expansion with a preliminary expansion schedule,
- reclamation plan,
- environmental protection plan, and
- type and quantity of estimated production.

These terms fulfilled, a lease can be issued. The fee per hectare should be large enough to deter speculative applications. It also should be reasonably high to ensure a fair return to the public and also to make the use of private peatlands competitive by ensuring that there is no unfair advantage to using public land because of low fees.

The lease should be given only for a suitable number of years. Formerly, land has been leased (e.g. New Brunswick) up to 99 years without any conditions imposed upon the leaseholder. However, this leads into speculative practices. A lease renewable every 10 years could be considered. However, to be renewable, or even held the full term, the holder should be required to show a certain minimum expenditure per hectare annually towards development of the leased land. Also, the holder should show a certain increase in total production geared into the size of the leased area and its production potential.

The lease should be issued only for a certain deposit on which survey work and the above mentioned plans have been submitted for. The leased area should cover some specified area. In New Brunswick, the leased "modules" are set at 250 ha while in Minnesota they may be 1,500 ha.

In case of very large deposits, over 1,000 ha in size, it is preferable to set a maximum lease size. However, in any case the lease size should be subject to a reasonably executable expansion and production plan. Thus, if the applicant is capable of showing his financial and technical capacity to progress quickly and develop areas larger than 1,000 hectares in size, he should be allowed to apply for them. Also, in case of a group of smaller peatlands, a lease could cover a number of bogs which form a discrete unit for the proposed operation. In case only a portion of a large deposit is leased, surrounding areas should not be leased out to exclude the expansion of the existing operation.

7.4.5 ROYALTY

A royalty, based either on weight or volume of the peat produced and preferably indexed to the production rate and marketing value, should be levied to ensure a fair return to the public. However, the royalty should not be too high to exclude possible smaller operations because of a financial burden.

7.5 ENVIRONMENTAL ASPECTS

7.5.1 RESPONSIBILITY

Before a peat lease is issued, the applicant should present a plan for environmental protection on future reclamation of the mined-out area. Generally, the operator is deemed to be responsible for implementing the plan and monitoring the water and air quality. For this, and the reclamation purposes, a bond may be required. This practice is common in the mining industry. However, in case of a small-scale peat operation, a bond could be a burden discouraging people from getting into peat mining. In most cases, the disruption caused by peat mining would probably be of a minor significance in comparison with e.g. strip mining for coal. In case of reclamation, the actual act of reclaiming a certain parcel of peat mining terrain may be 30-40 years in the future. Considering all these aspects, in case of small-scale operations in an area of high unemployment, it may be more feasible to use the taxes generated by the new industry to finance environmental and reclamation costs. In the case of large-scale operations, a performance bond could be the avenue to take.

7.5.2 AIR AND WATER QUALITY

7.5.2.1 PLAN TO PROTECT AIR AND WATER

A plan to ensure that no severe impact on the hydrological and air conditions is created by a peat mining and processing operation should be submitted. The plan should describe the methods to be taken to prevent effluent from the peat mine and the processing plants from harming the adjacent water bodies. Procedures to minimize the release of peat dust, both from the mine and processing plant, as well as the release of gases from a processing plant (e.g. gasifier) should be described.

7.5.2.2 MONITORING

A plan for monitoring the effluents from the peat mine and plant should be presented. Various items, such as pH, gaseous materials, dust, etc. should be measured and periodically monitored at the mine and plant site to ensure an acceptable low level of release.

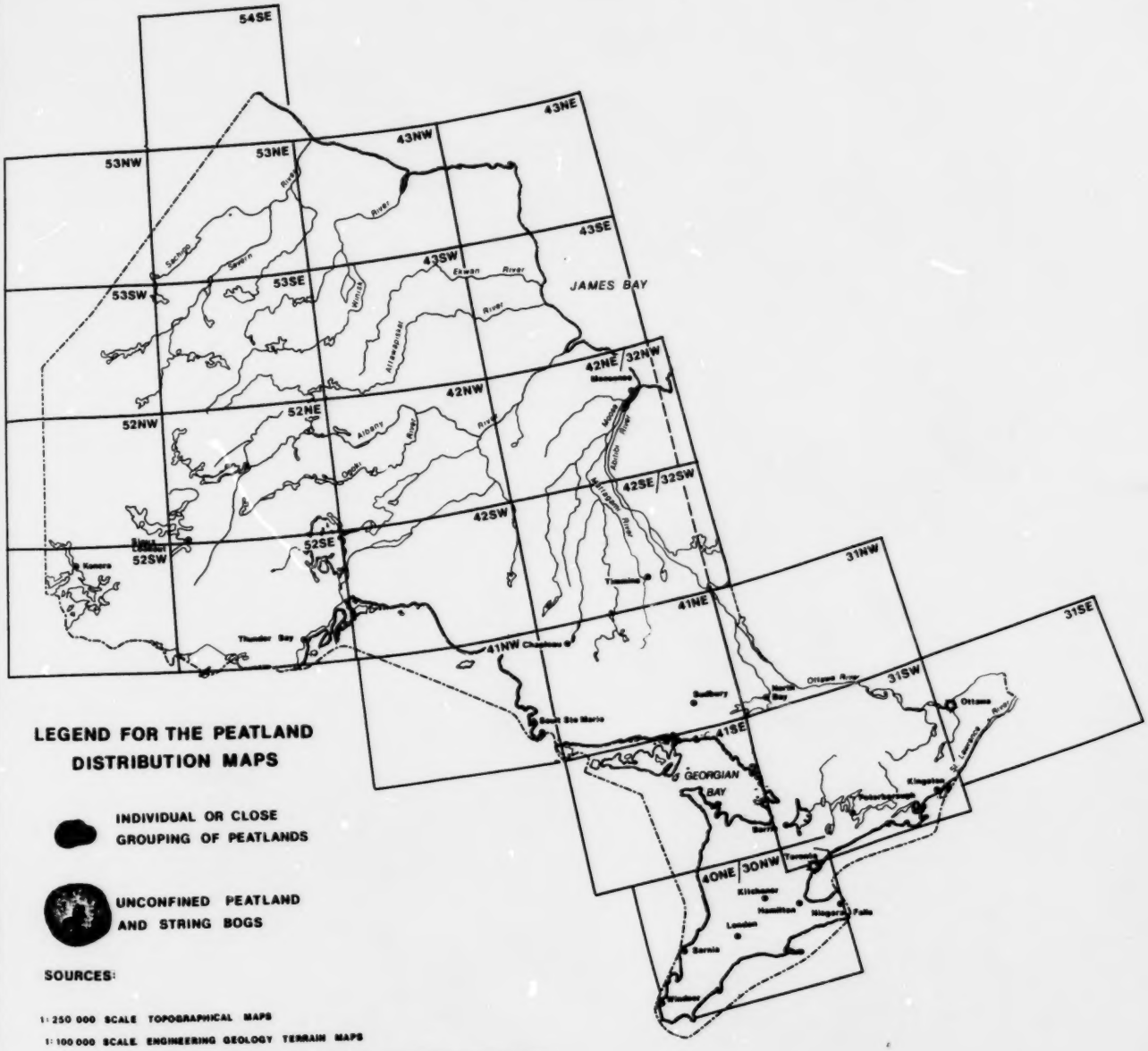
7.5.2.3 RECLAMATION

A reclamation plan should address both the sequential multi-use of the peat resource as well as the final reclamation procedures and modes. As peat mining progresses at a specified location, different peat types are encountered and selective mining, simultaneously for energy and non-energy, may be the most efficient use of the resource. Also, towards the end of the mine life, depending on the demand and local conditions, various end-uses may materialize. Such uses are reclamation for forestry, agriculture, wildlife, recreation or allowing the area to revert back to its original state.

7.6 SUMMARY

The regulatory procedures are a complex matter and will need research in depth into both the literature on the environmental effects of peatland drainage, mining and processing elsewhere, and into existing regulations in Europe and North America. A comprehensive listing of all the environmental effects and possible remedies and mitigative methods were beyond the scope of the present work. Close cooperation will be required between the governmental departments responsible for policy formulations as well as a committee or consultant responsible for the technical and socio-economic details. It is difficult to divorce policy and the actual technical details from each other. Close cooperation, it is hoped, will lead to development of a sound system which will enhance the utilization of peat, with a proper element of regulatory constraints to ensure an environmentally acceptable industry, without too constrictive regulations.

APPENDIX A
Generalized Peatland Distribution Maps of Ontario



LEGEND FOR THE PEATLAND DISTRIBUTION MAPS

INDIVIDUAL OR CLOSE GROUPING OF PEATLANDS

UNCONFINED PEATLAND AND STRING BOGS

SOURCES:

1:250 000 SCALE TOPOGRAPHICAL MAPS

1:100 000 SCALE ENGINEERING GEOLOGY TERRAIN MAPS

PLATE A-1. NTS INDEX OF PEATLAND DISTRIBUTION MAPS.

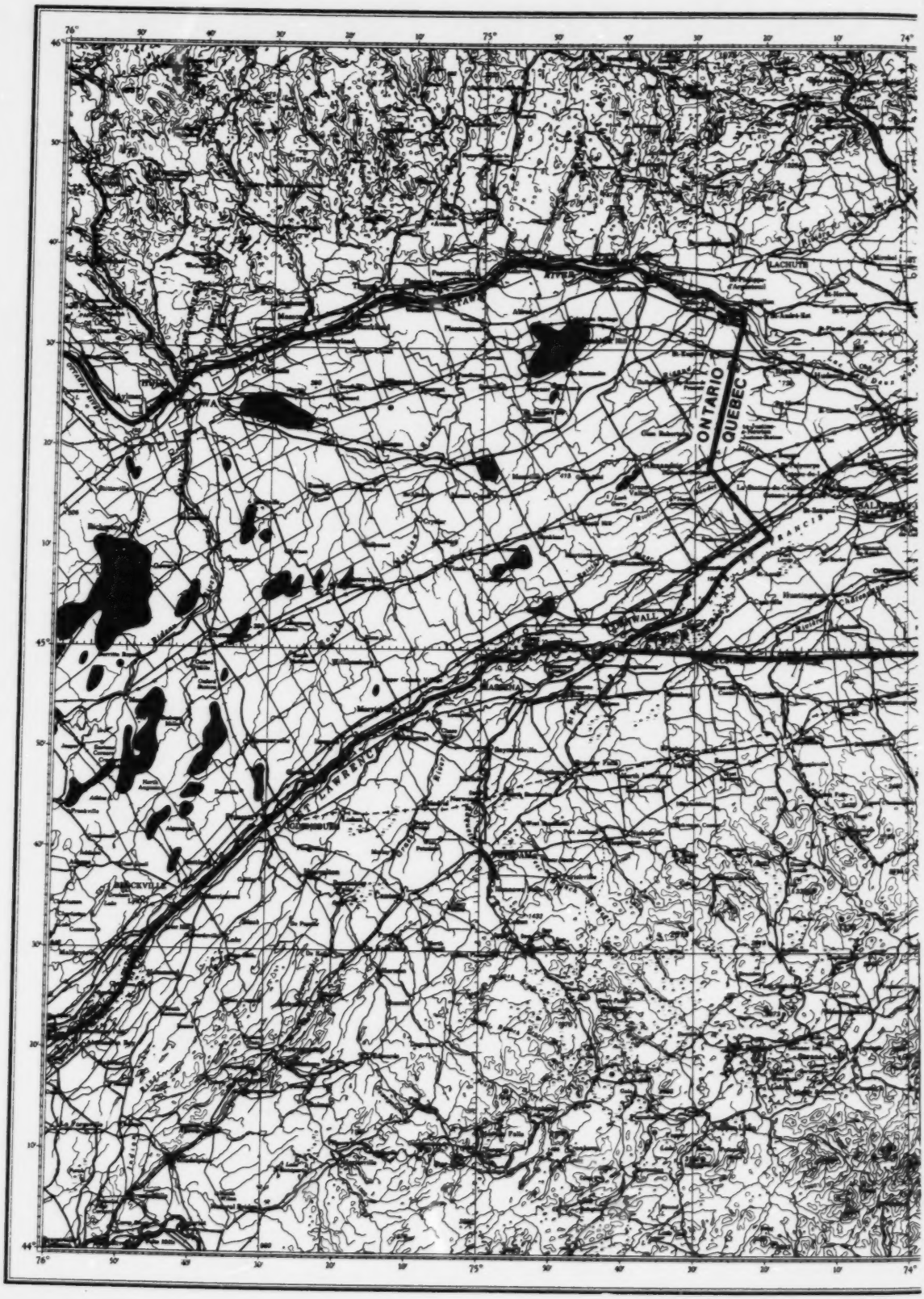


PLATE A-2. PEATLAND DISTRIBUTION FOR NTS AREA 31 SE, OTTAWA - MONTREAL.

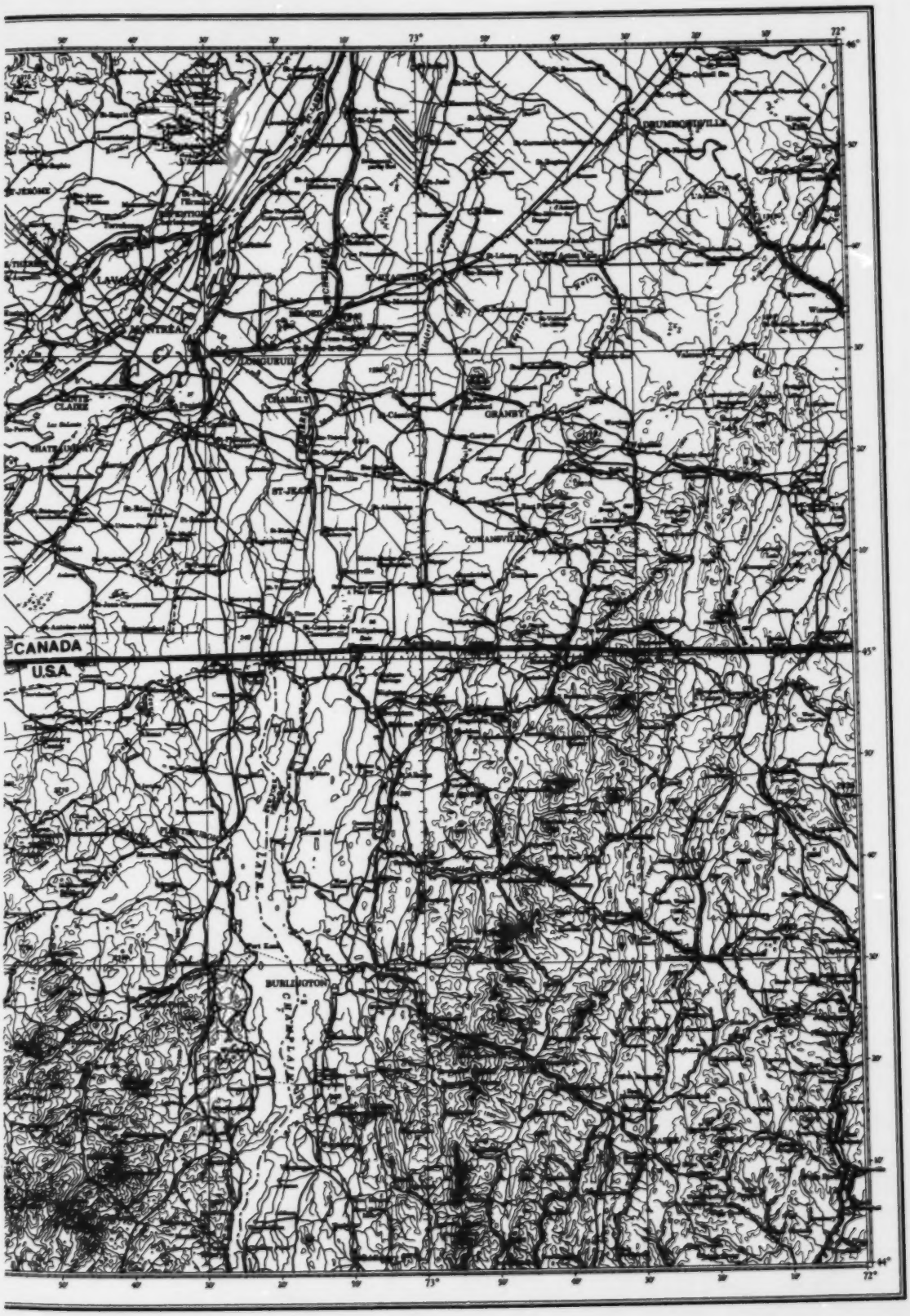

CANADA
U.S.A.
MONTRÉAL
LONGUEUIL
GRANBY
BURLINGTON

PLATE A-3. PEATLAND DISTRIBUTION FOR NTS AREA 31 SW, TORONTO - OTTAWA.

QUEBEC
ONTARIO
ONTARIO
QUEBEC

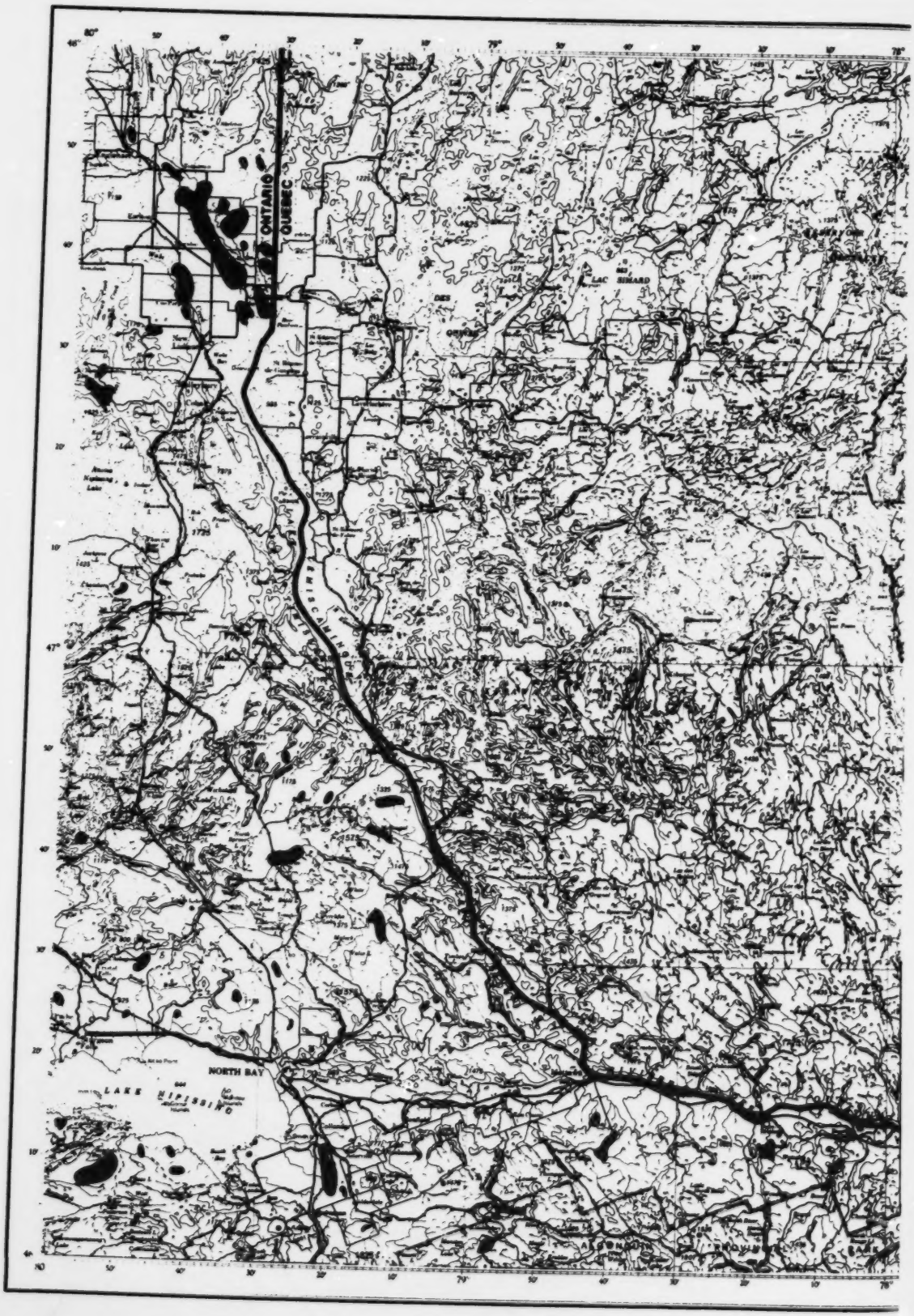
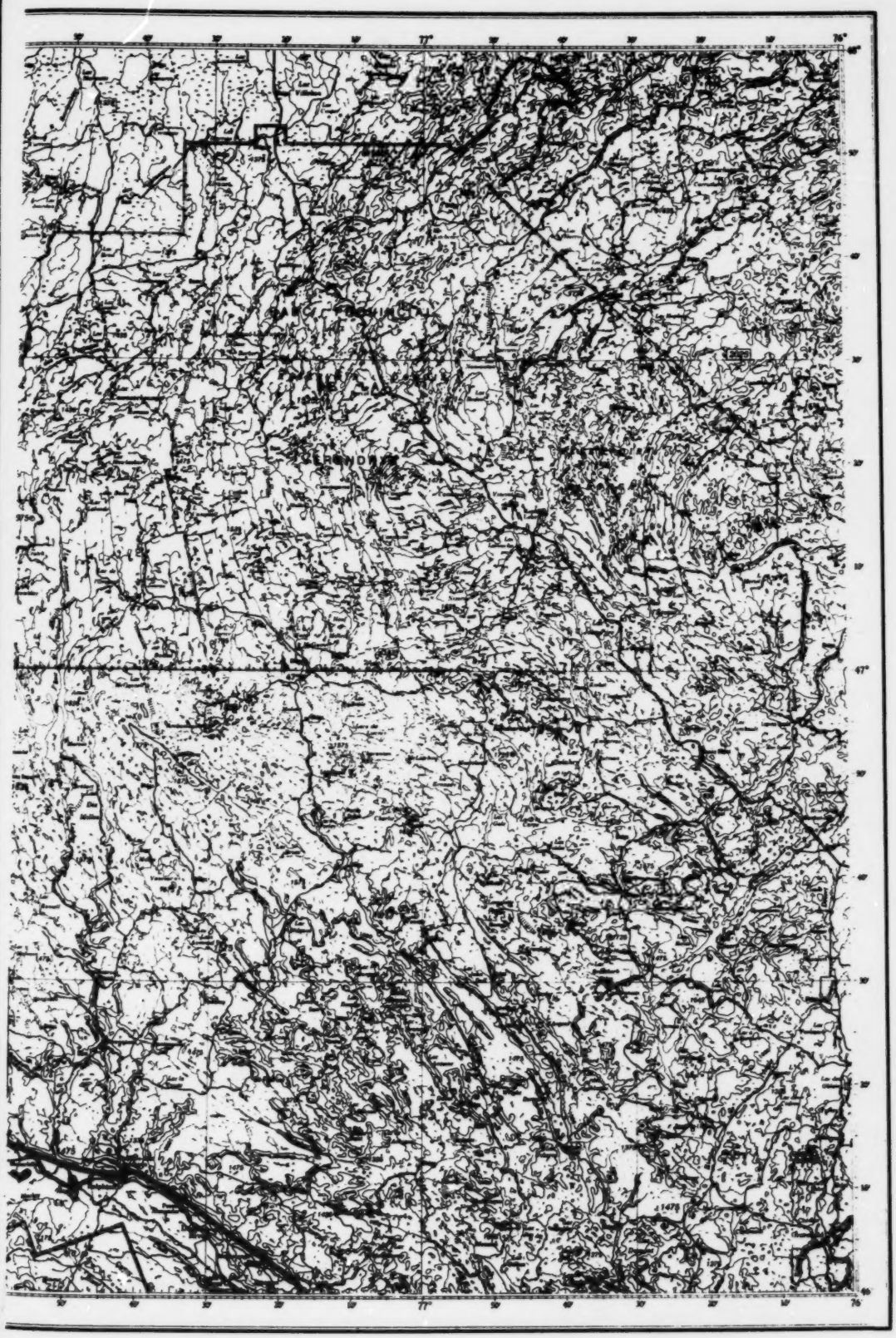


PLATE A-4. PEATLAND DISTRIBUTION FOR NTS AREA 31 NW, UPPER OTTAWA RIVER.



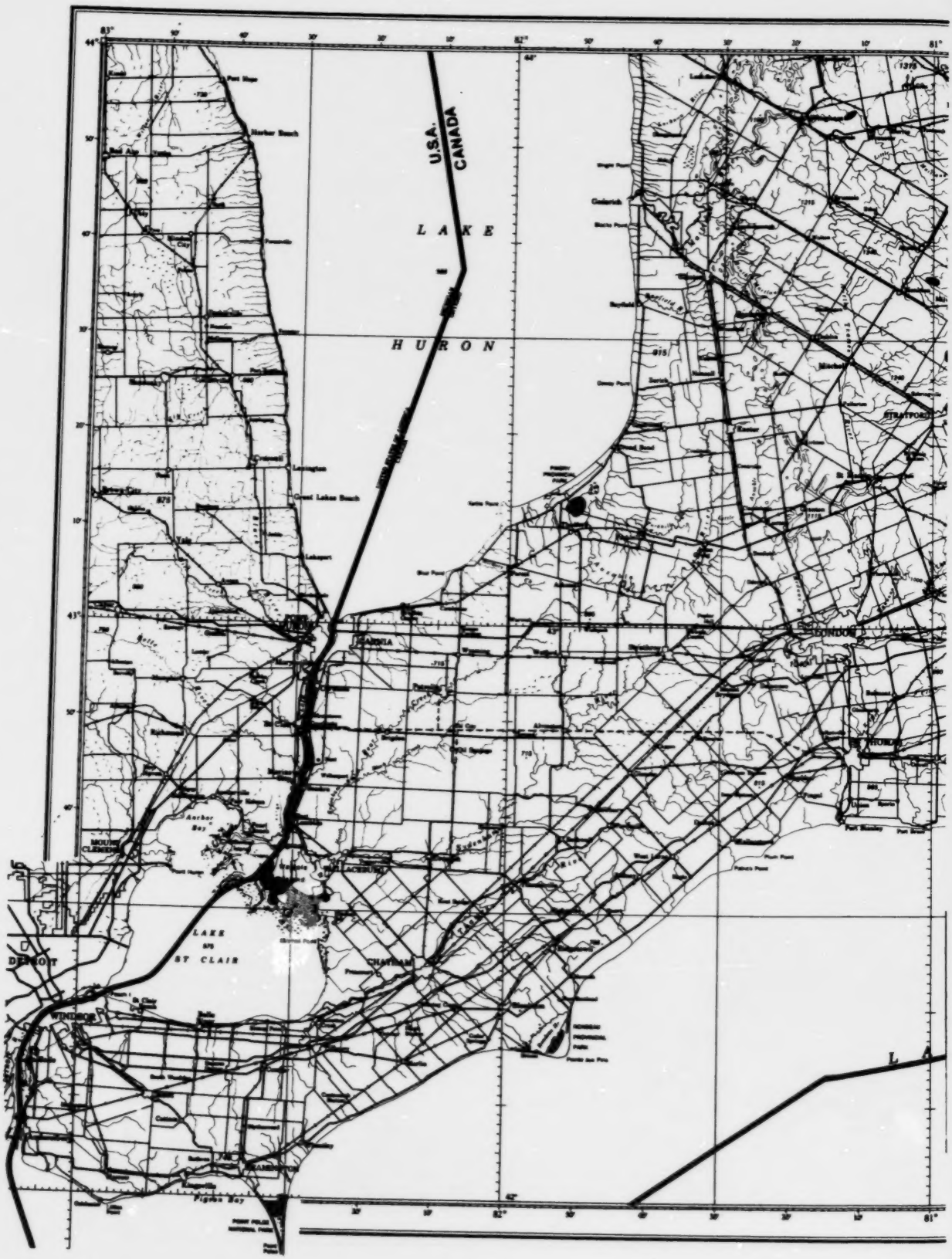


PLATE A-5. PEATLAND DISTRIBUTION FOR NTS AREA 40 NE/30 NW, WINDSOR - TORONTO.

TORONTO
HAMILTON
BURLINGTON
OAKVILLE
GUELPH
KITCHENER
BRANTFORD
LAKE ONTARIO
NIAGARA ON-THE-LAKE
GRIMSBY
Port Dover
Long Point Bay
CANADA
U.S.A.
E R I E
DUNKIRK
FREDONIA

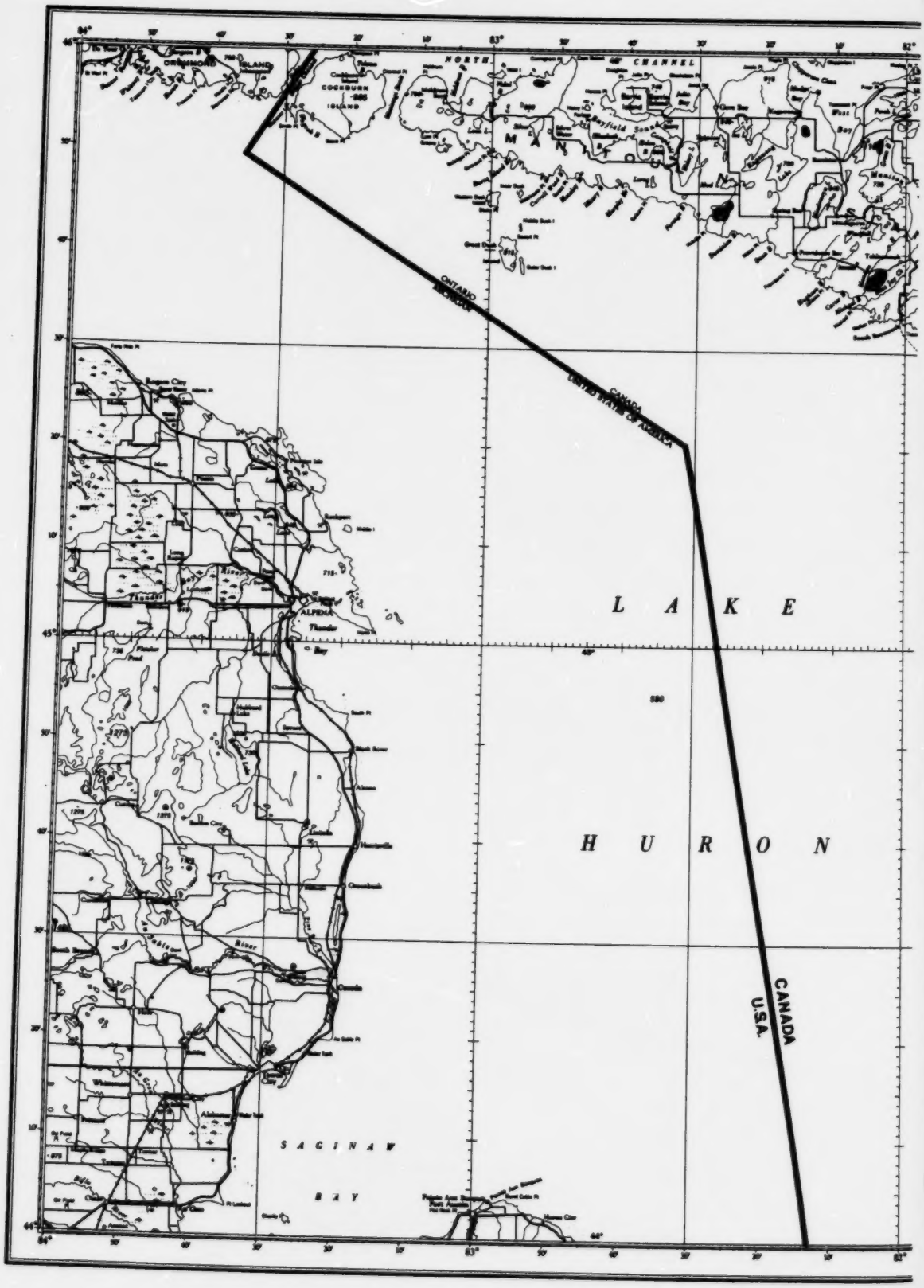
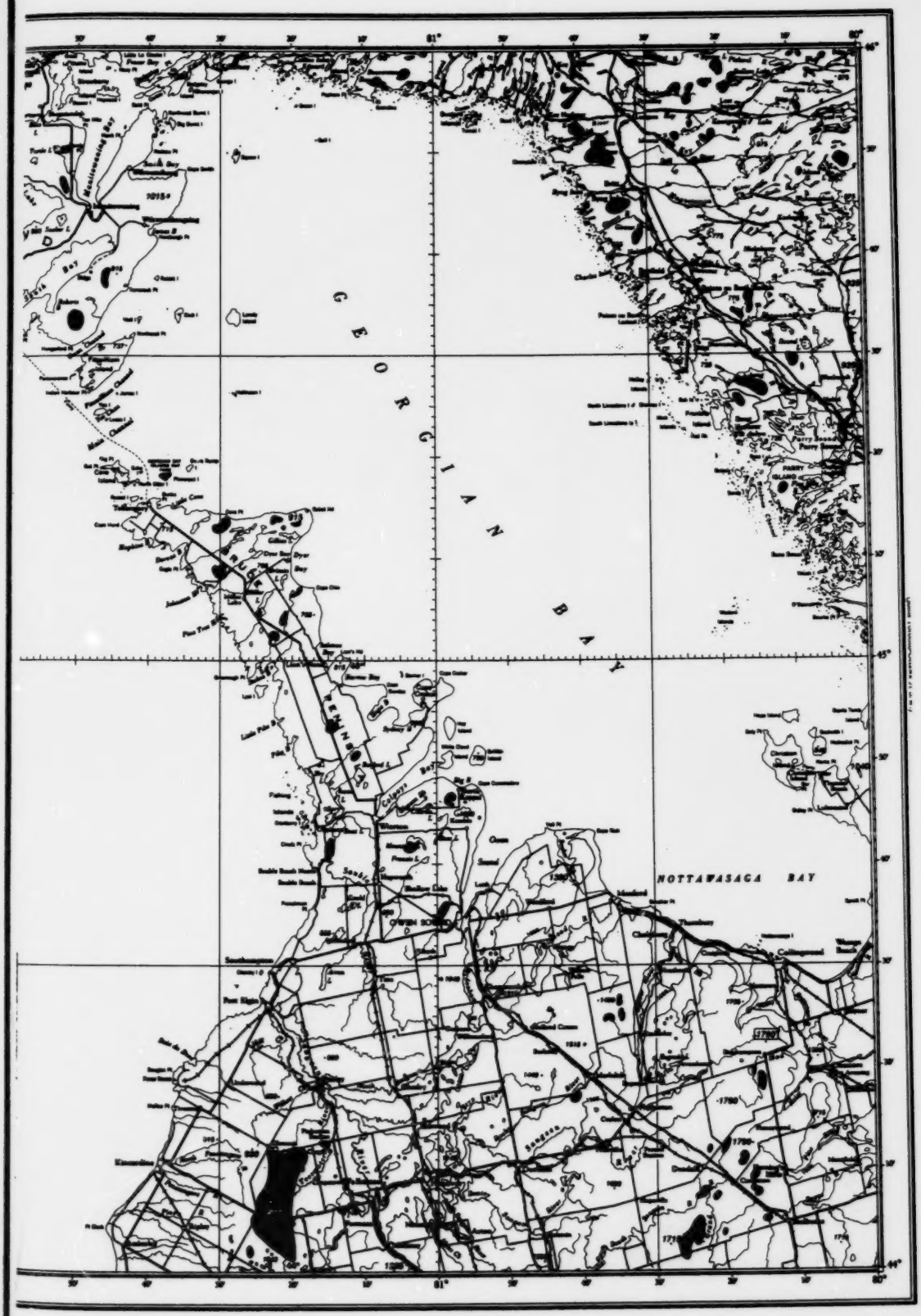


PLATE A-6. PEATLAND DISTRIBUTION FOR NTS AREA 41 SE, MANITOULIN - OWEN SOUND.


GEORGIAN BAY
NOTTAWASAGA BAY

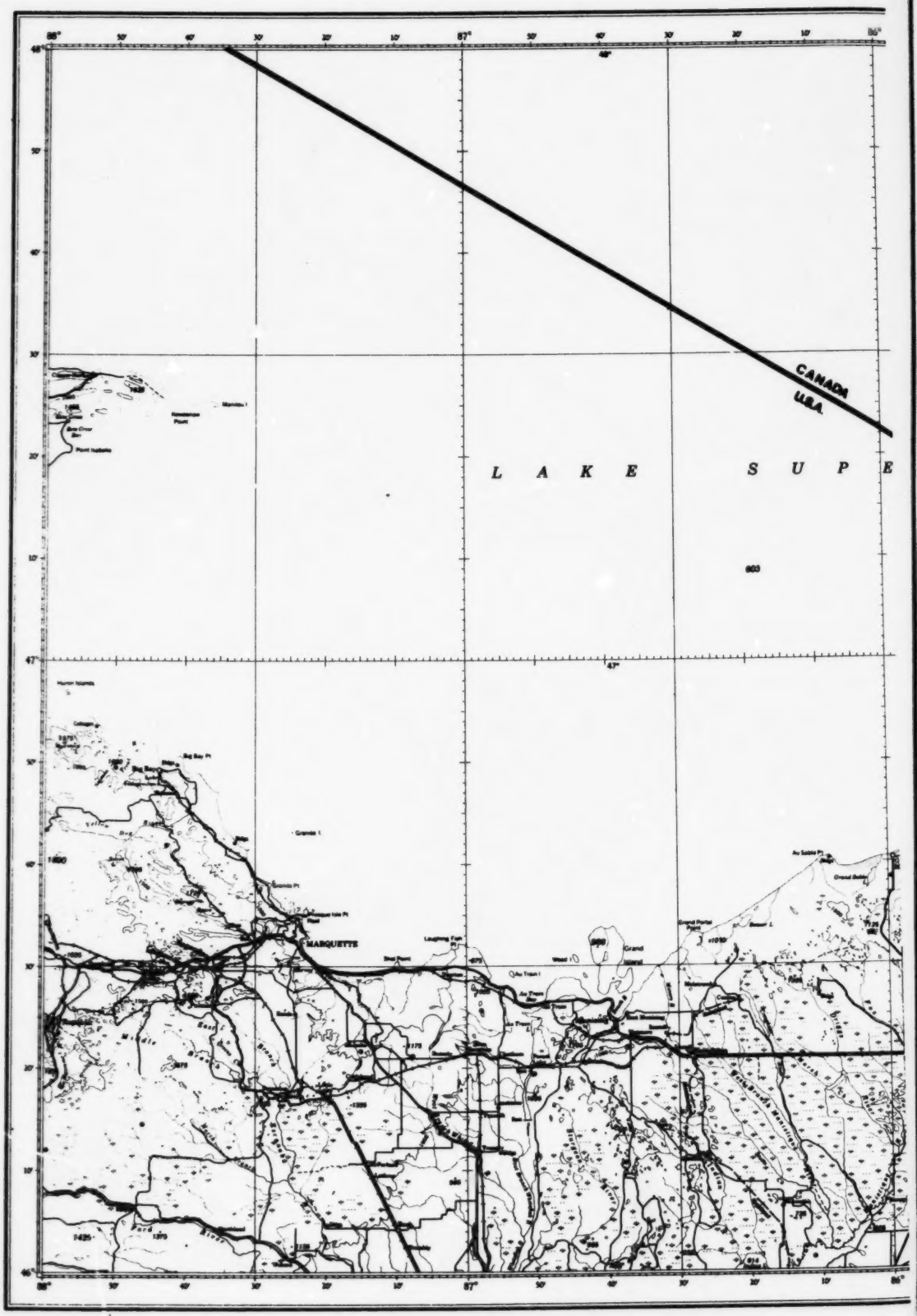


PLATE A-7. PEATLAND DISTRIBUTION FOR NTS AREA 41 NW, MICHIPICOTEN - SAULT STE. MARIE.

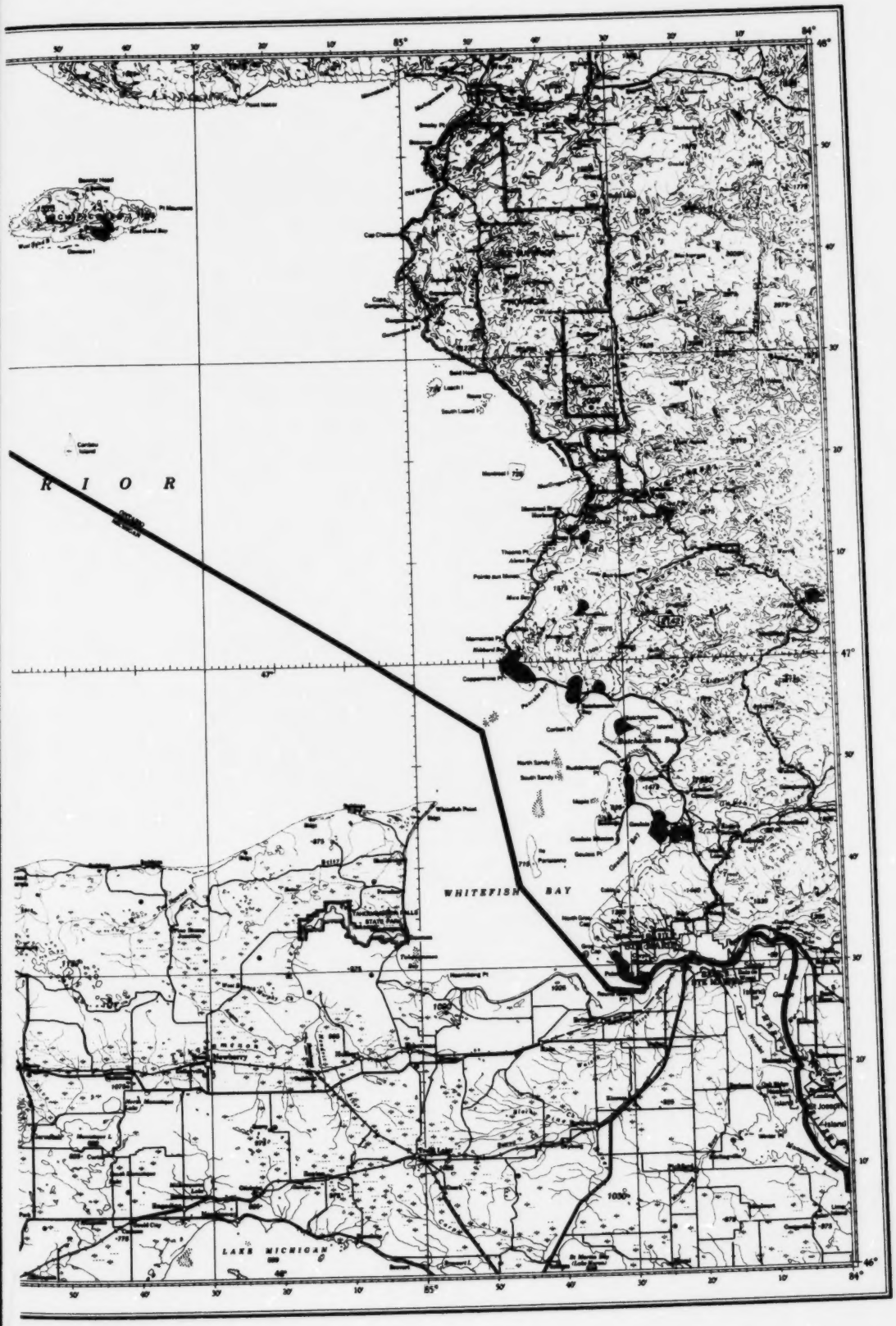

R I O R
WHITEFISH BAY
LAKE MICHIGAN

PLATE A-8. PEATLAND DISTRIBUTION FOR NTS AREA 41 NE, CHAPLEAU - SUDBURY.

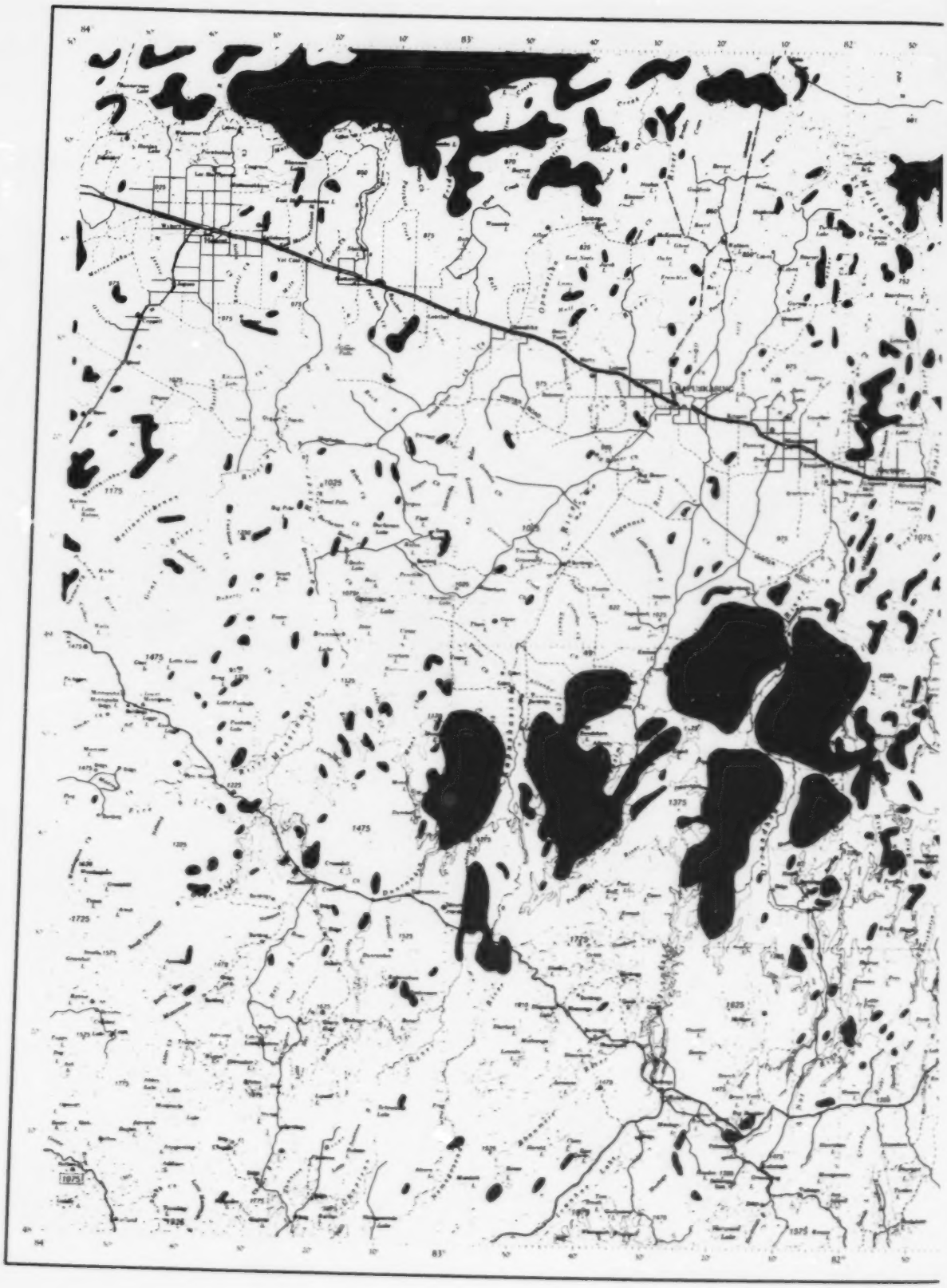
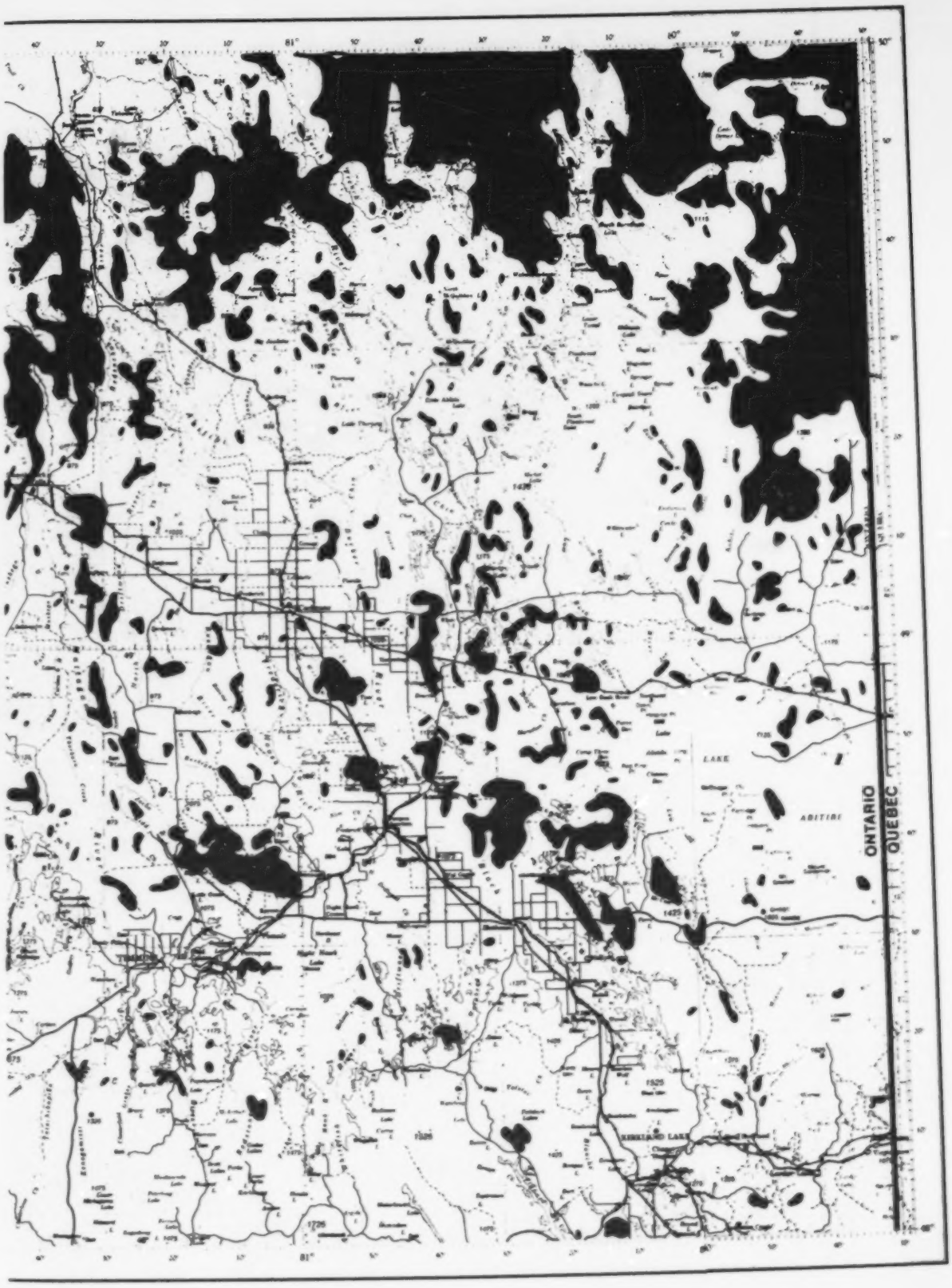


PLATE A-9. PEATLAND DISTRIBUTION FOR NTS AREA 42 SE/32 SW, HEARST - COCHRANE/NORANDA - WASWANIPI.


LAKE
ABITIBI
ONTARIO
QUEBEC

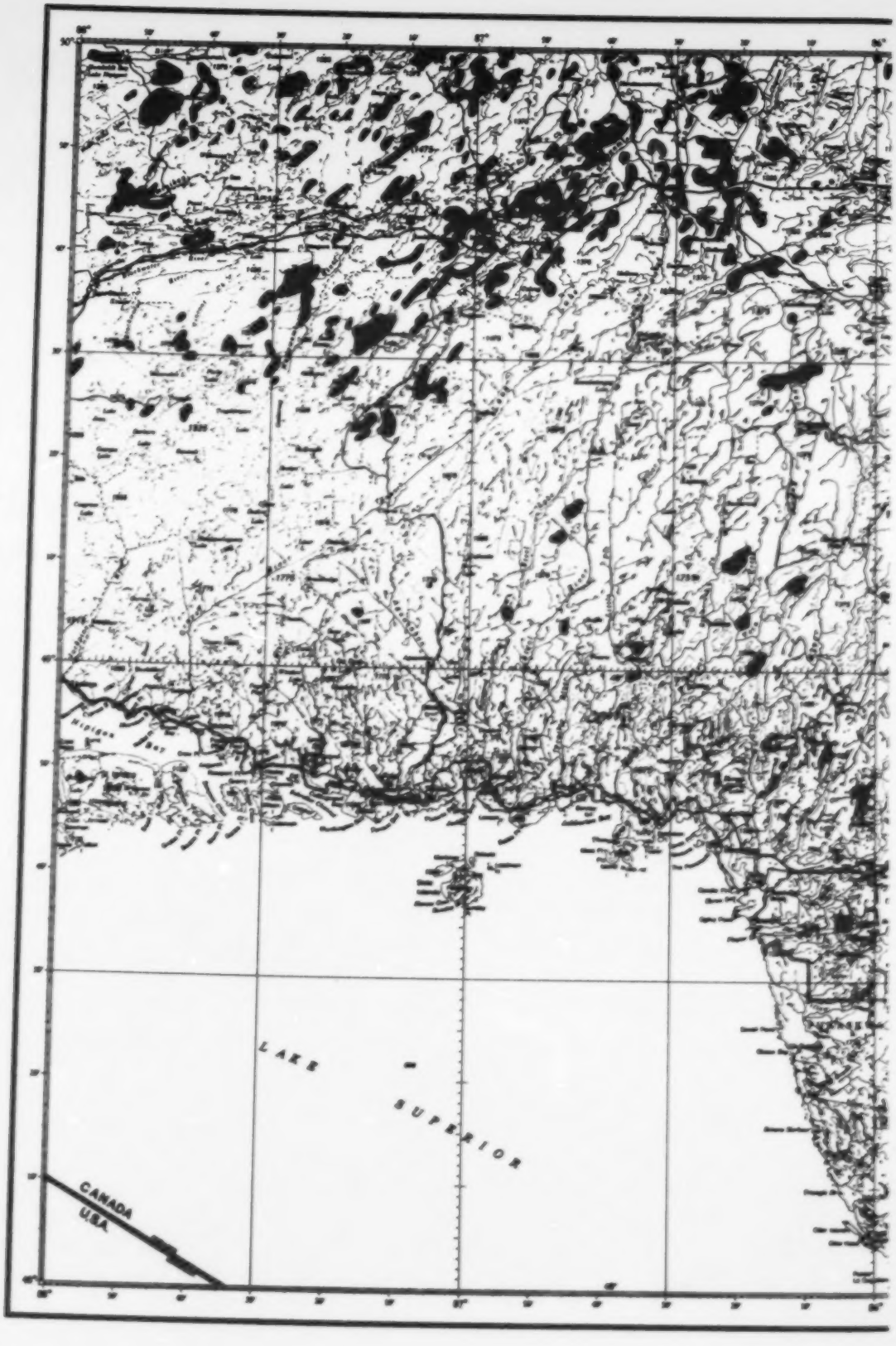
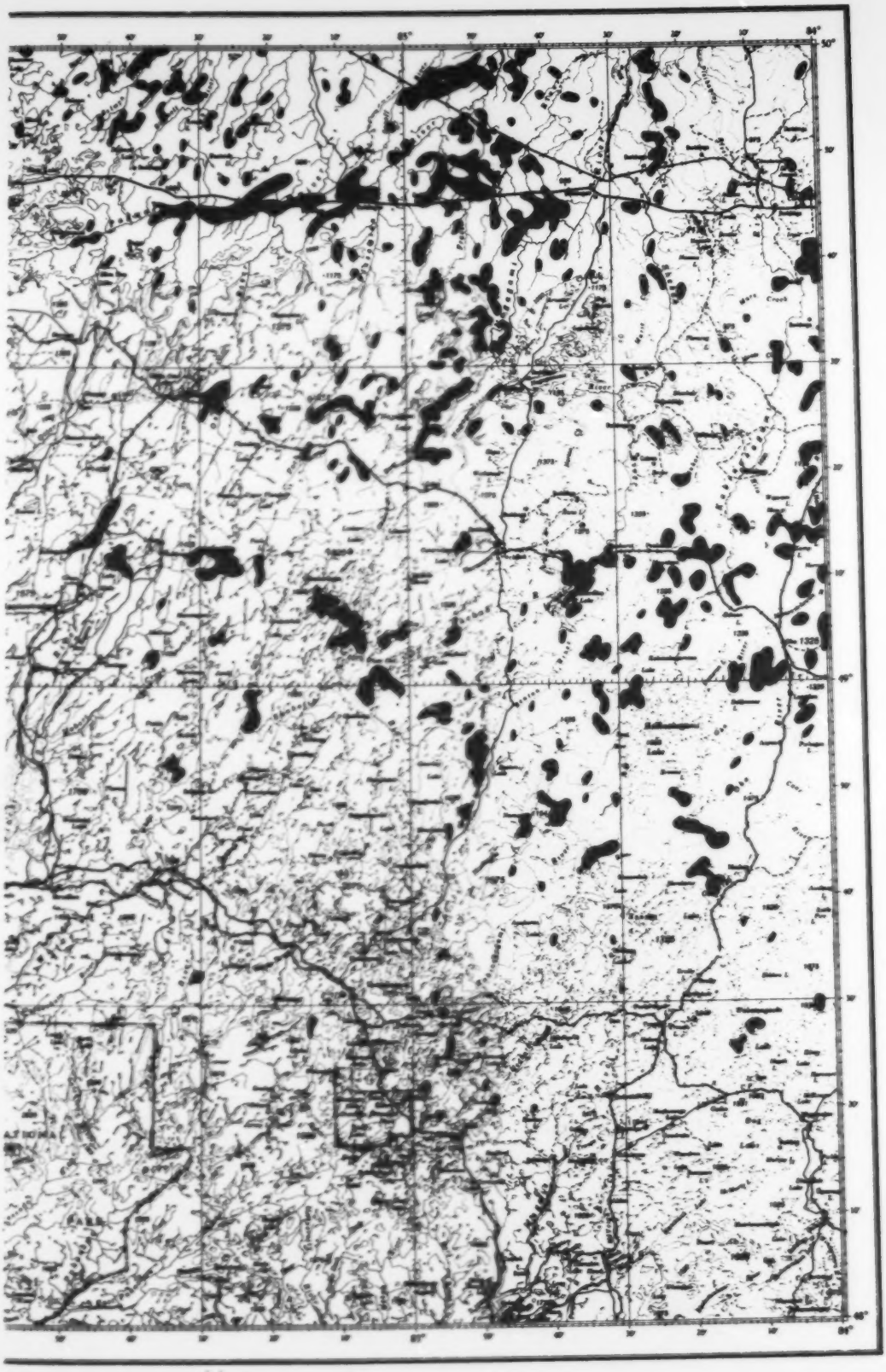


PLATE A-10. PEATLAND DISTRIBUTION FOR NTS AREA 42 SW, GERALDTON-WHITE RIVER.



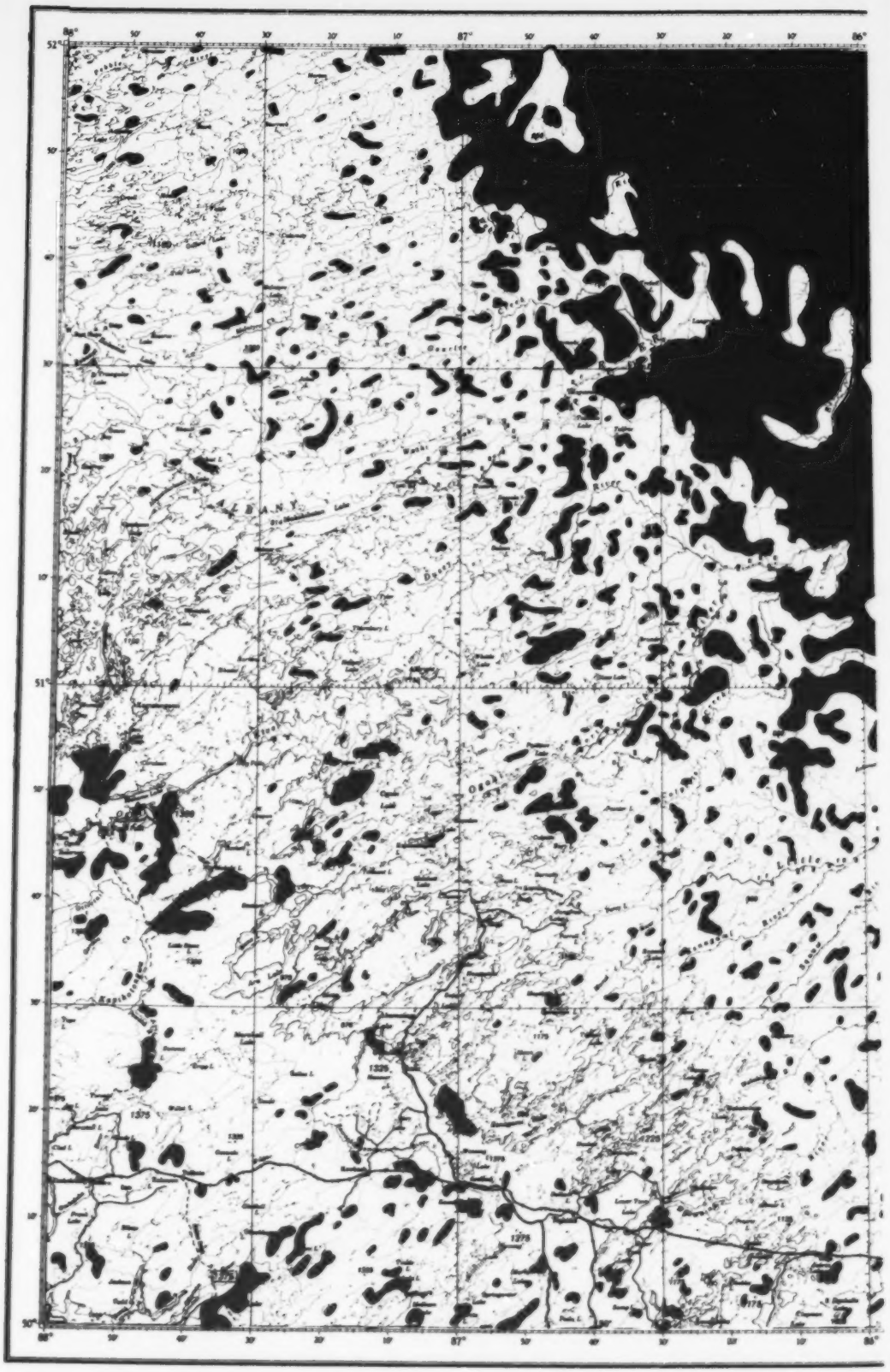
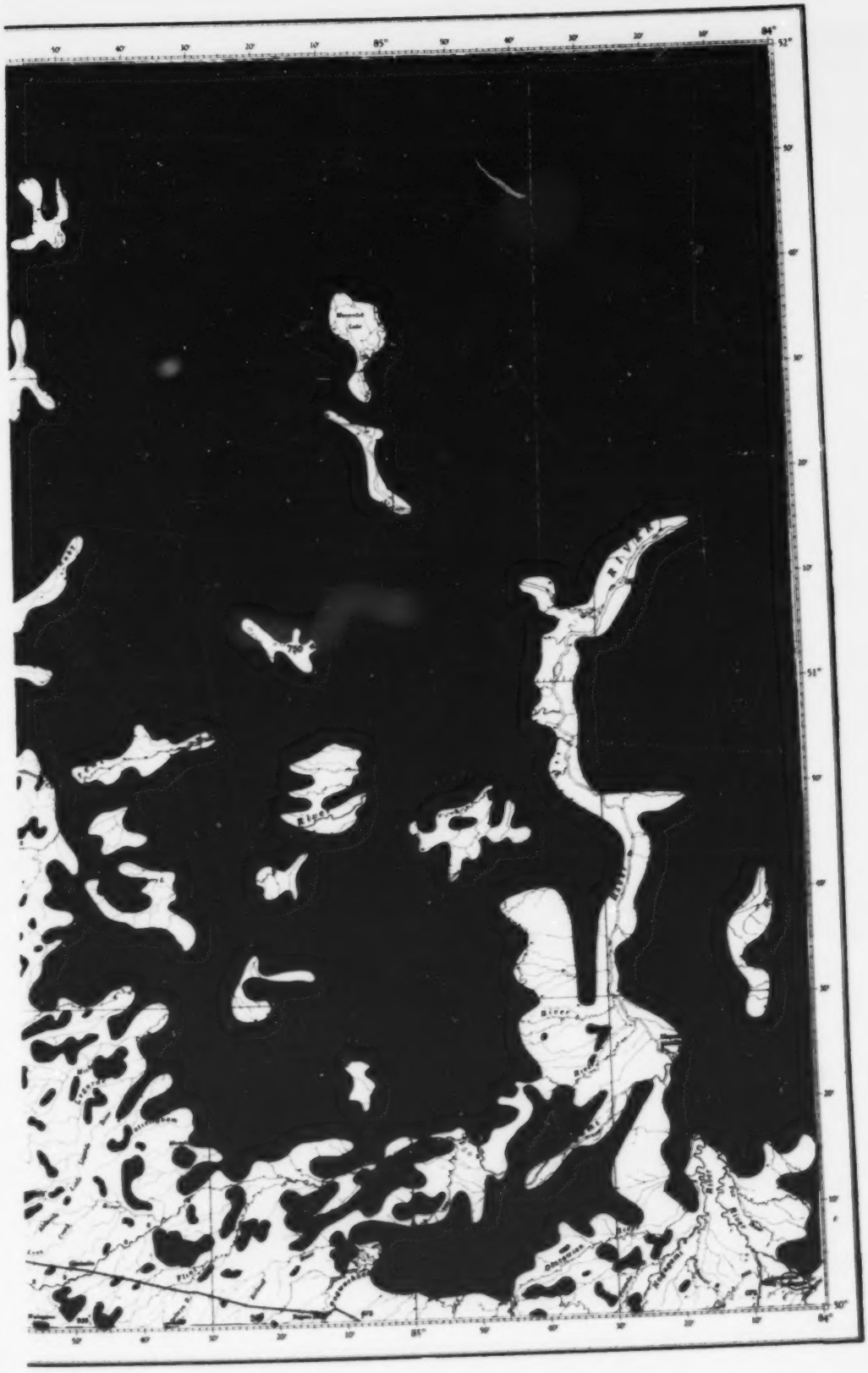


PLATE A-11. PEATLAND DISTRIBUTION FOR NTS AREA 42 NW, KOWKASH - MARTIN FALLS.



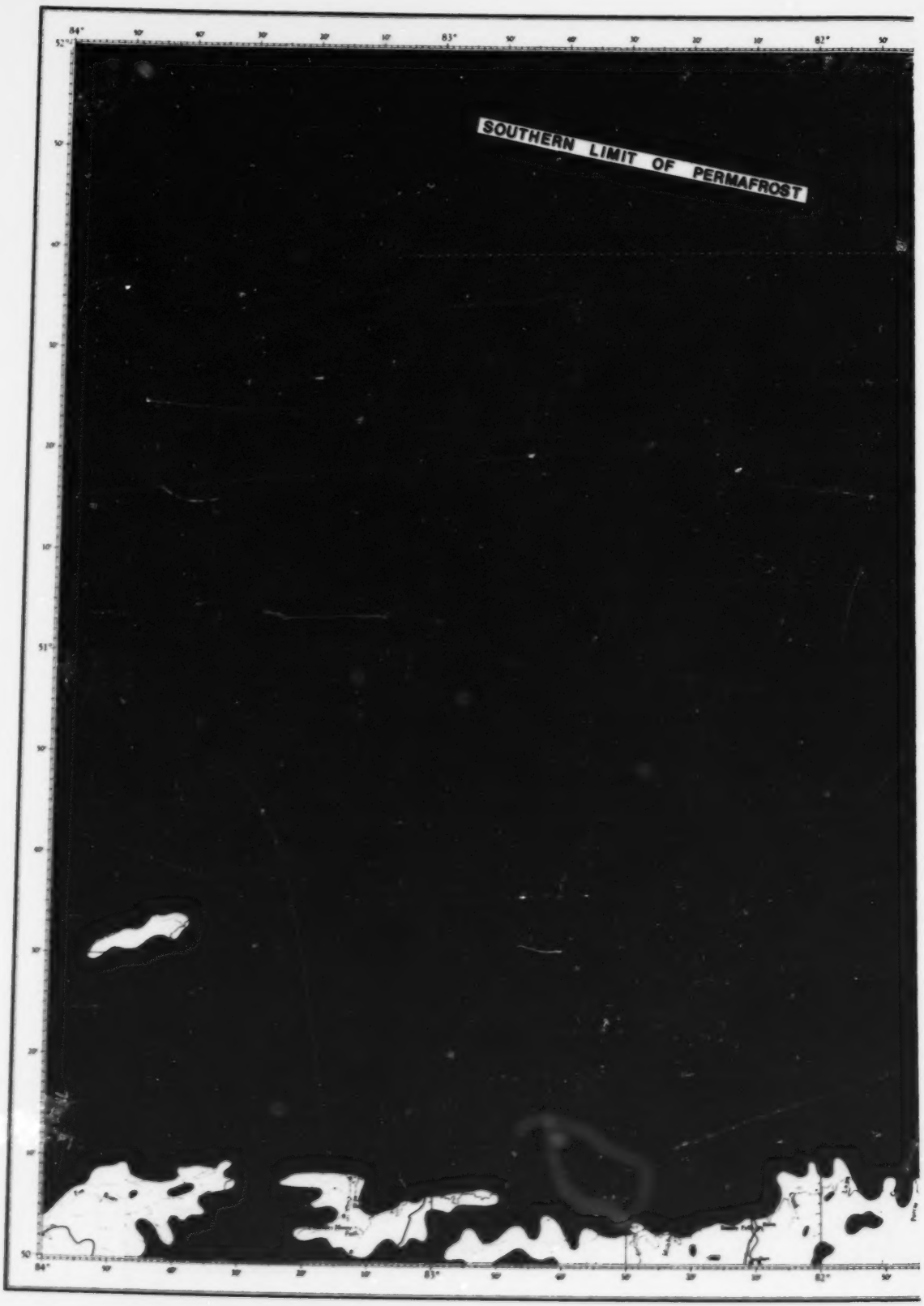


PLATE A-12. PEATLAND DISTRIBUTION FOR NTS AREA 42 NE/32 NW, MOOSONEE/FORT RUPERT.

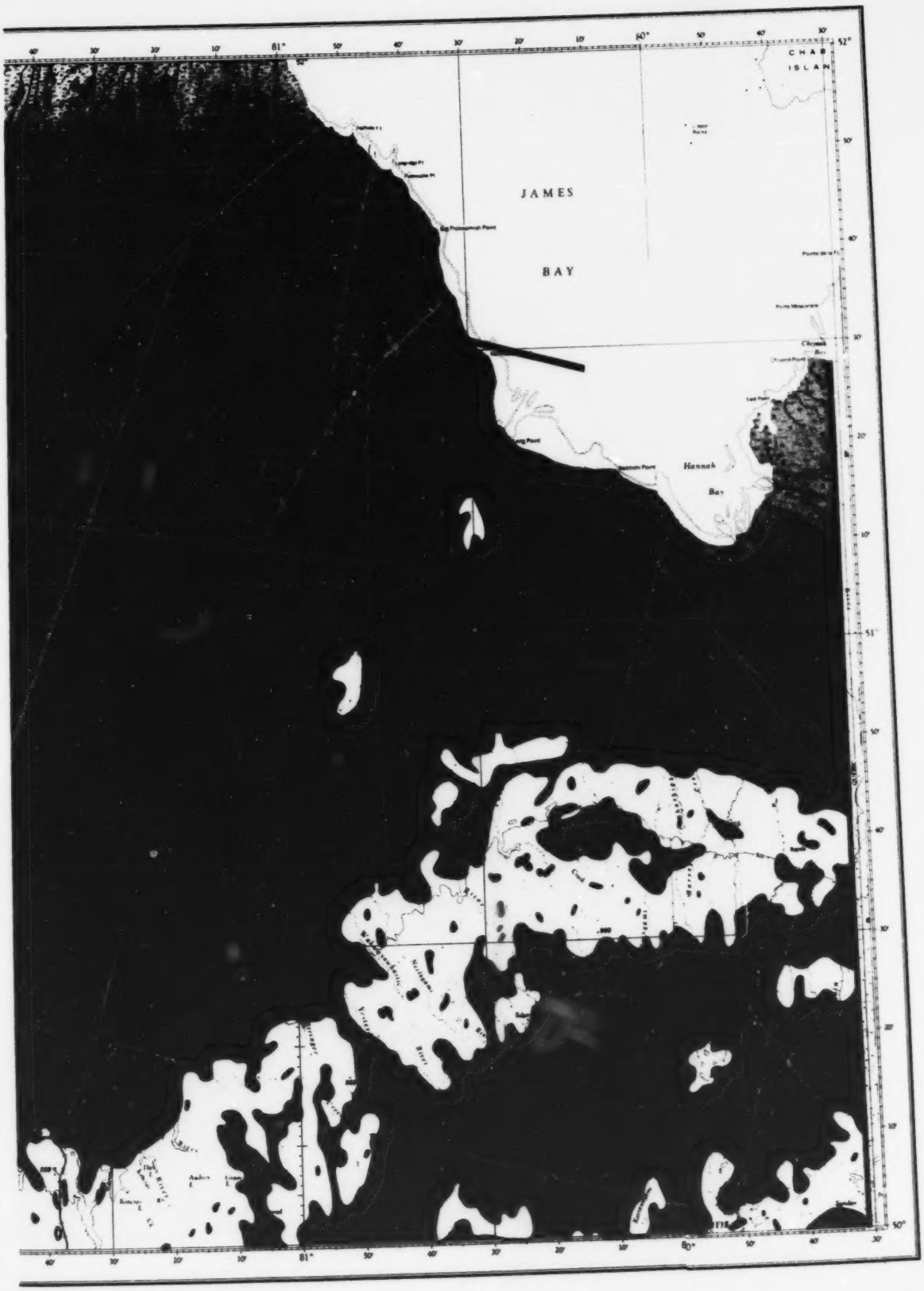
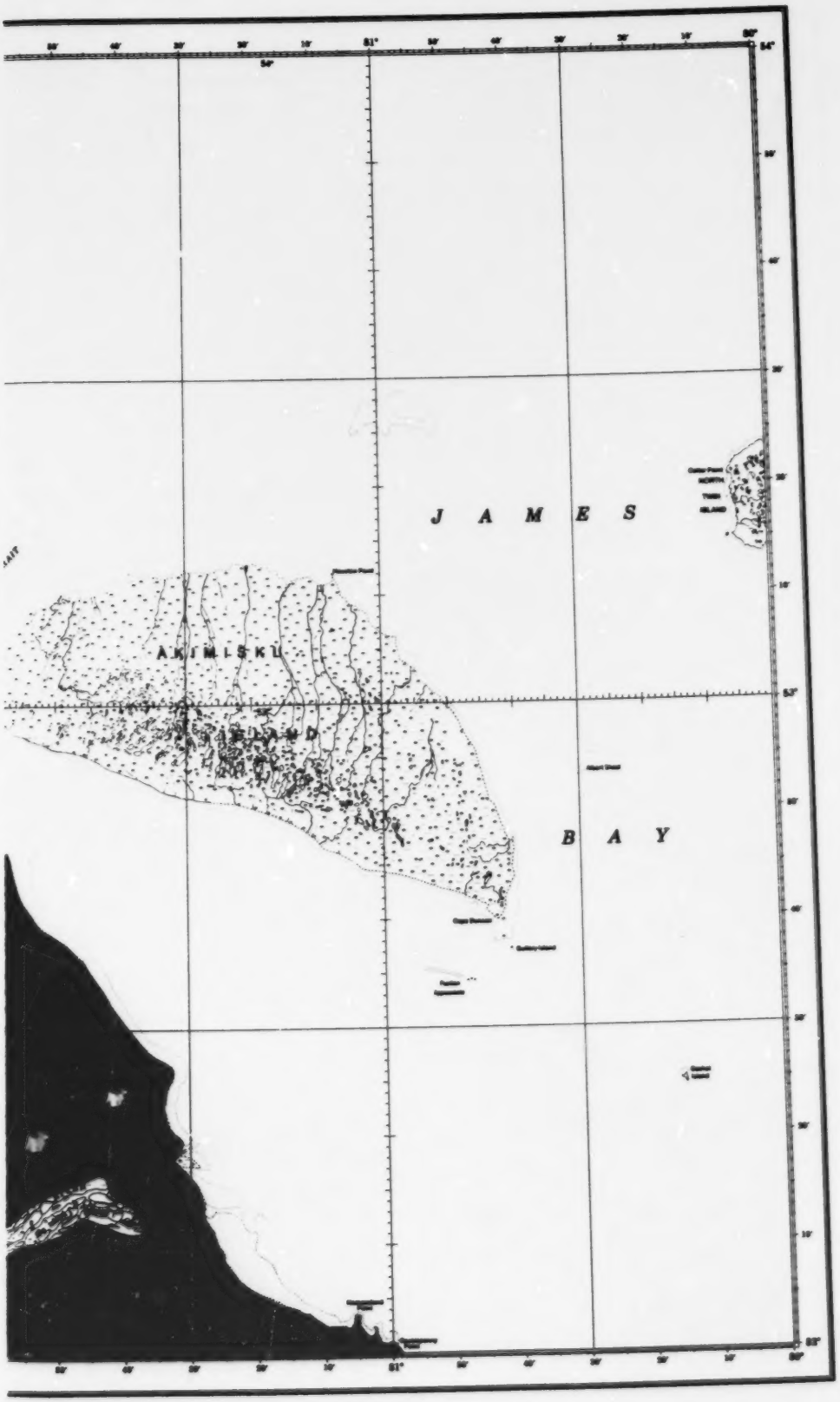

JAMES
BAY
Hannah
Bay

PLATE A-13. PEATLAND DISTRIBUTION FOR NTS AREA 43 SE, AKIMISKI ISLAND.


J A M E S
B A Y

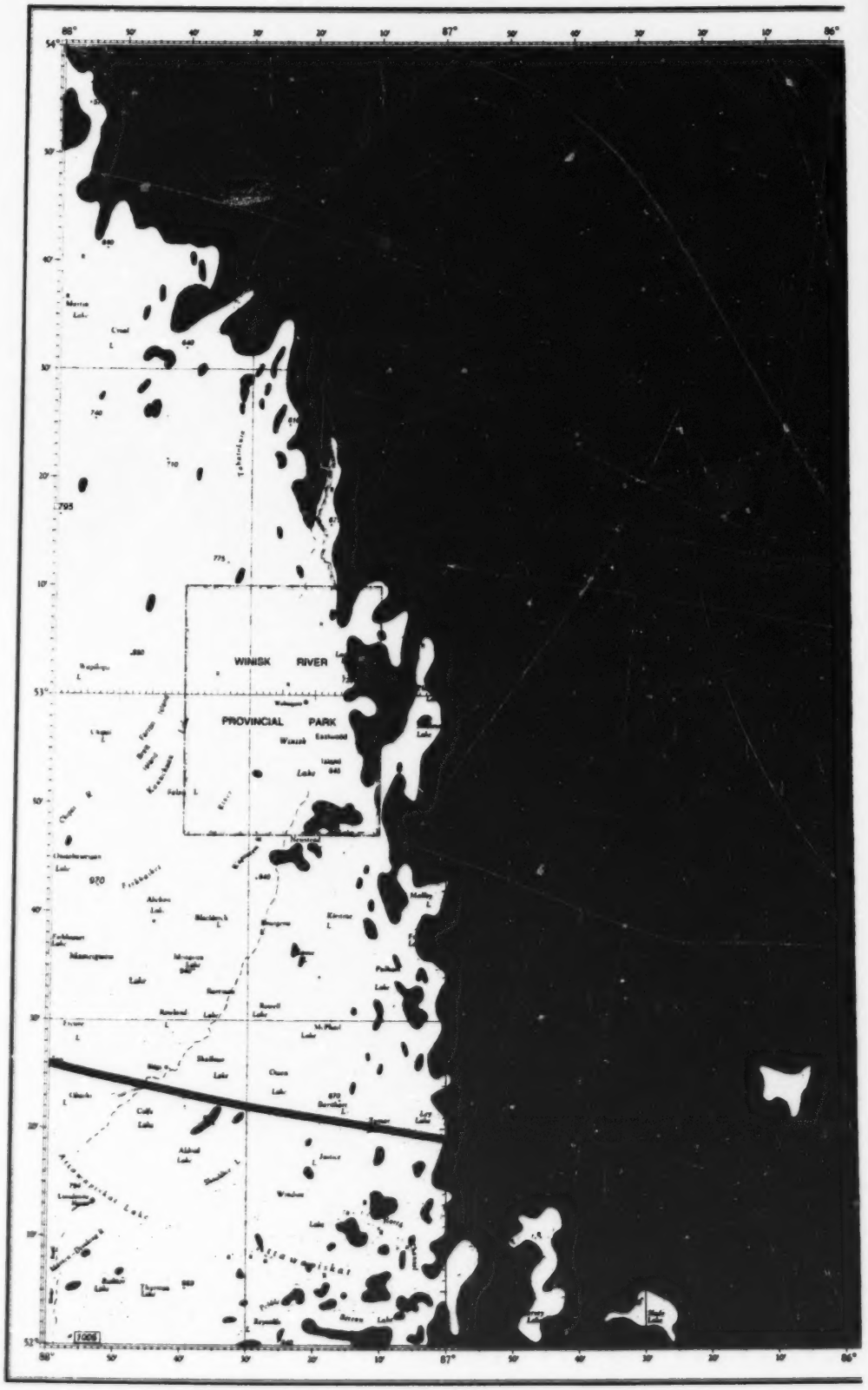
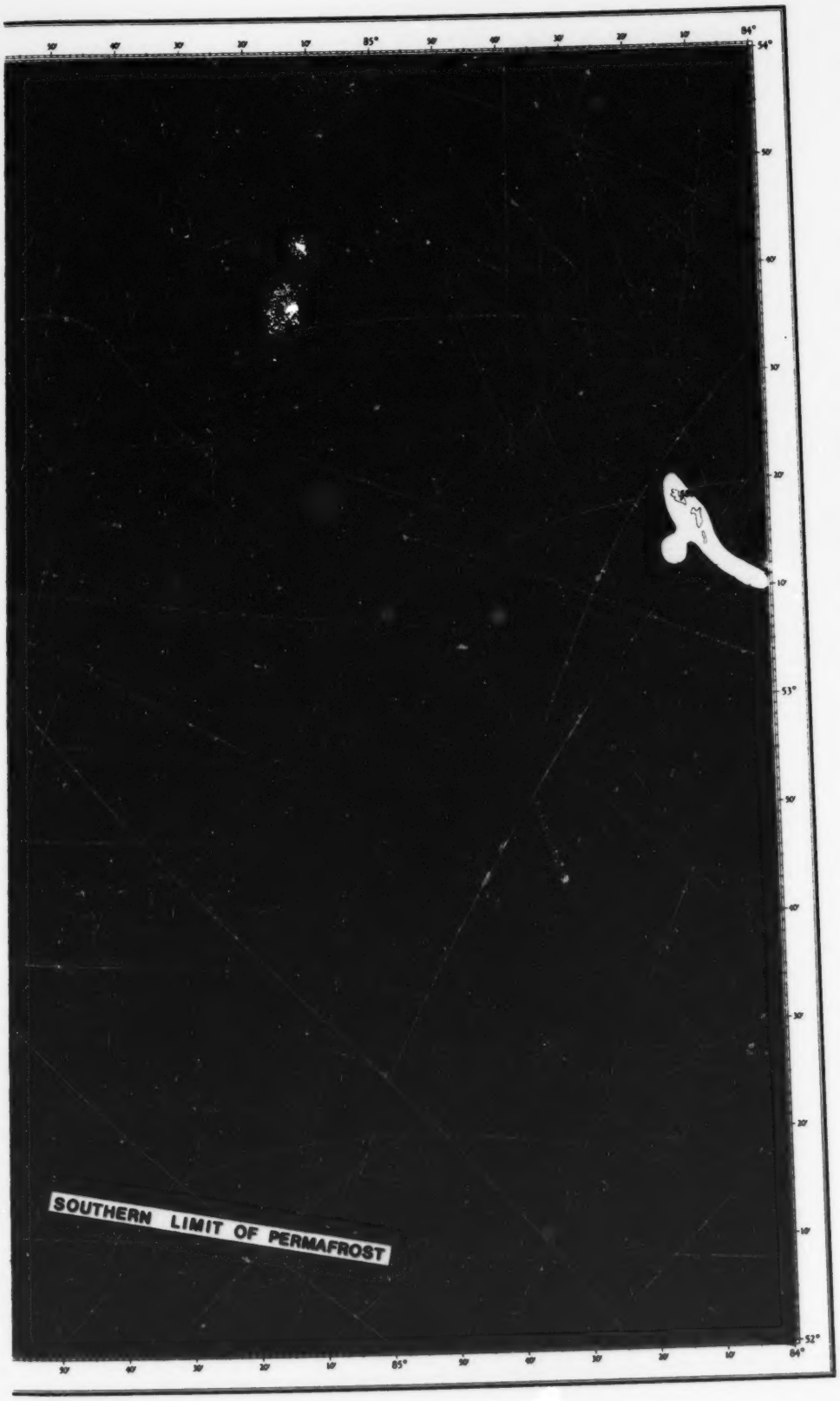


PLATE A-14. PEATLAND DISTRIBUTION FOR NTS AREA 43 SW, ATTAWAPISKAT.


SOUTHERN LIMIT OF PERMAFROST

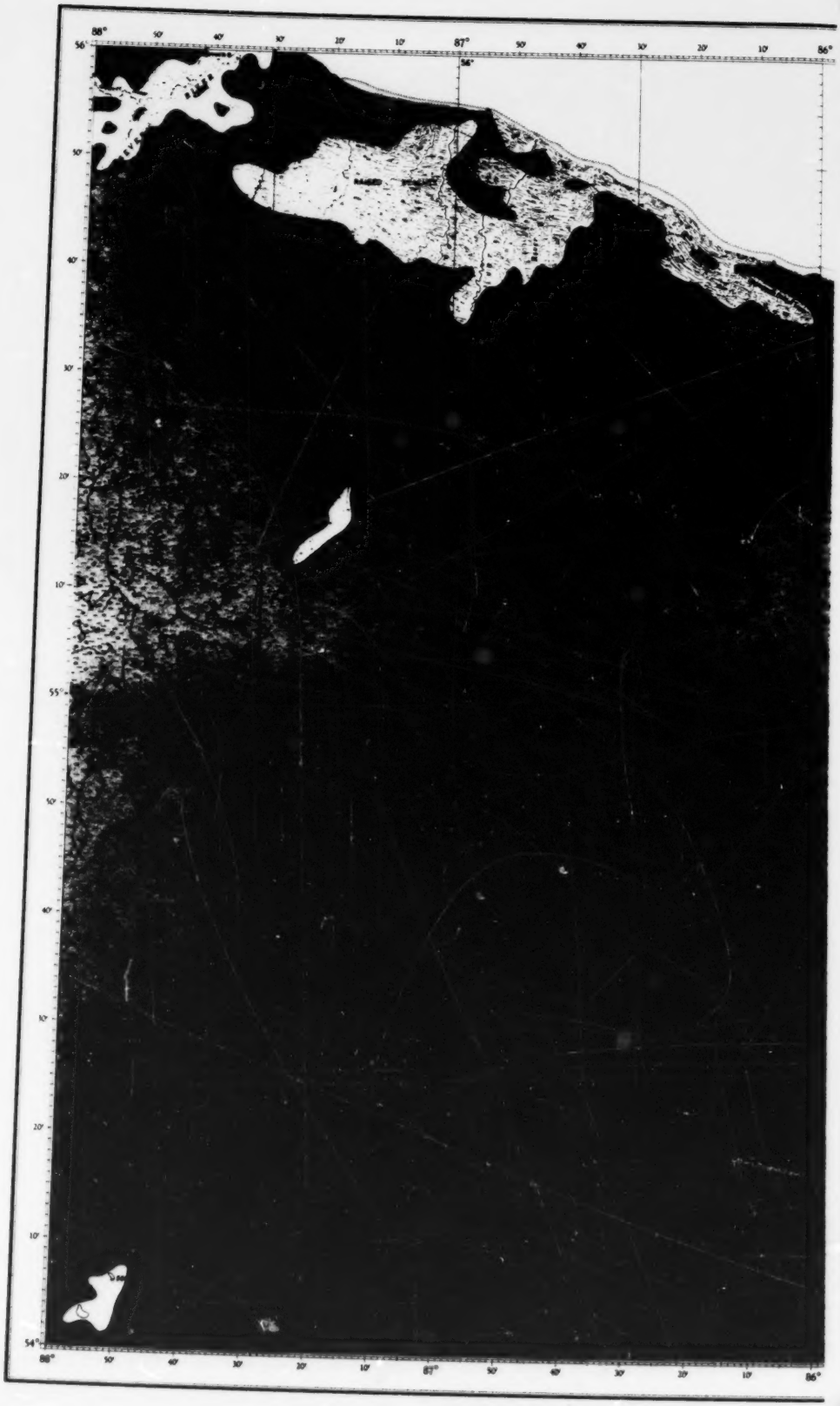


PLATE A-15. PEATLAND DISTRIBUTION FOR NTS AREA 43 NW, WINISK RIVER.

HUDSON
BAY

PLATE A-16. PEATLAND DISTRIBUTION FOR NTS AREA 43 NE, HENRIETTA MARIA.

B A Y
J A M E S B A Y

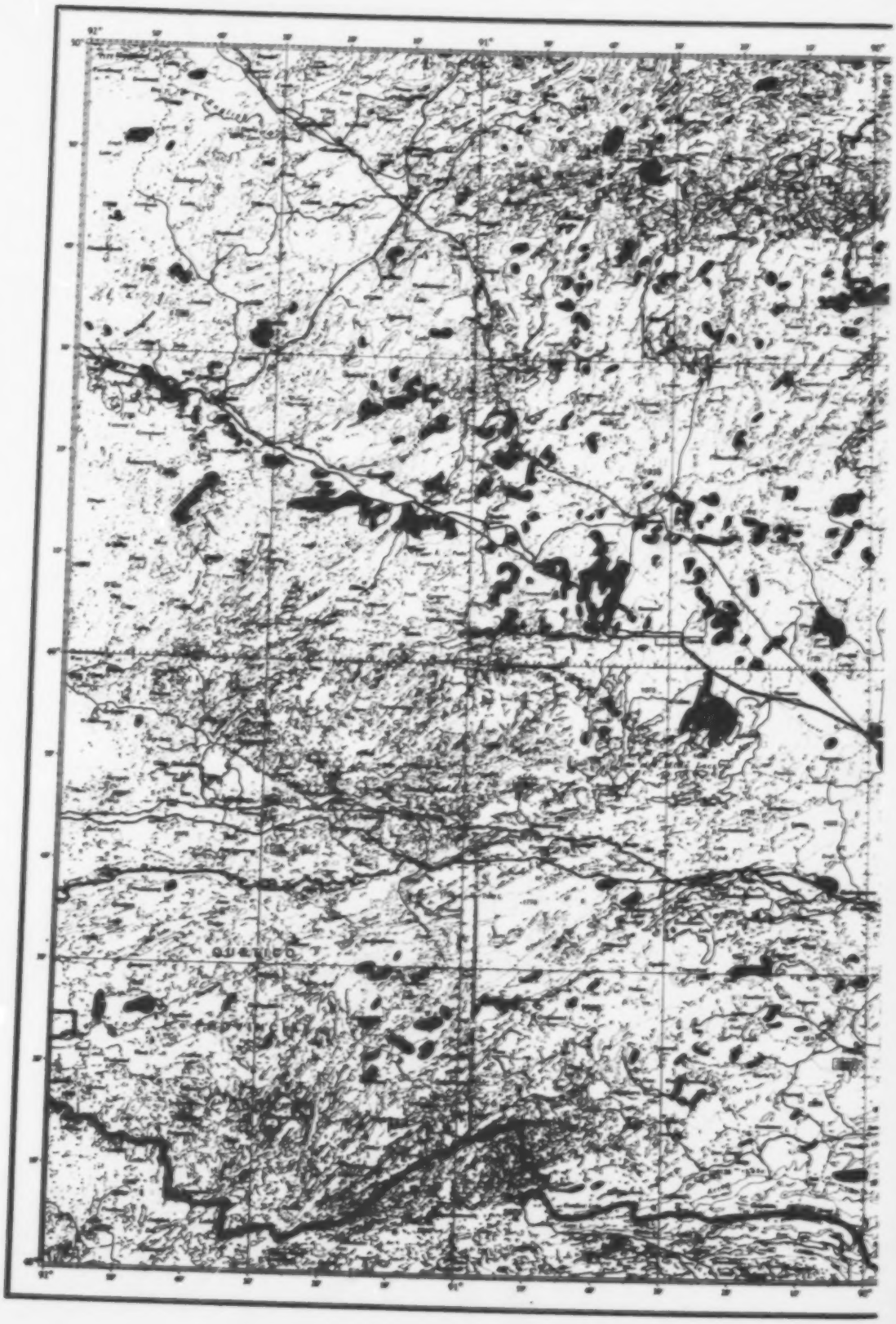
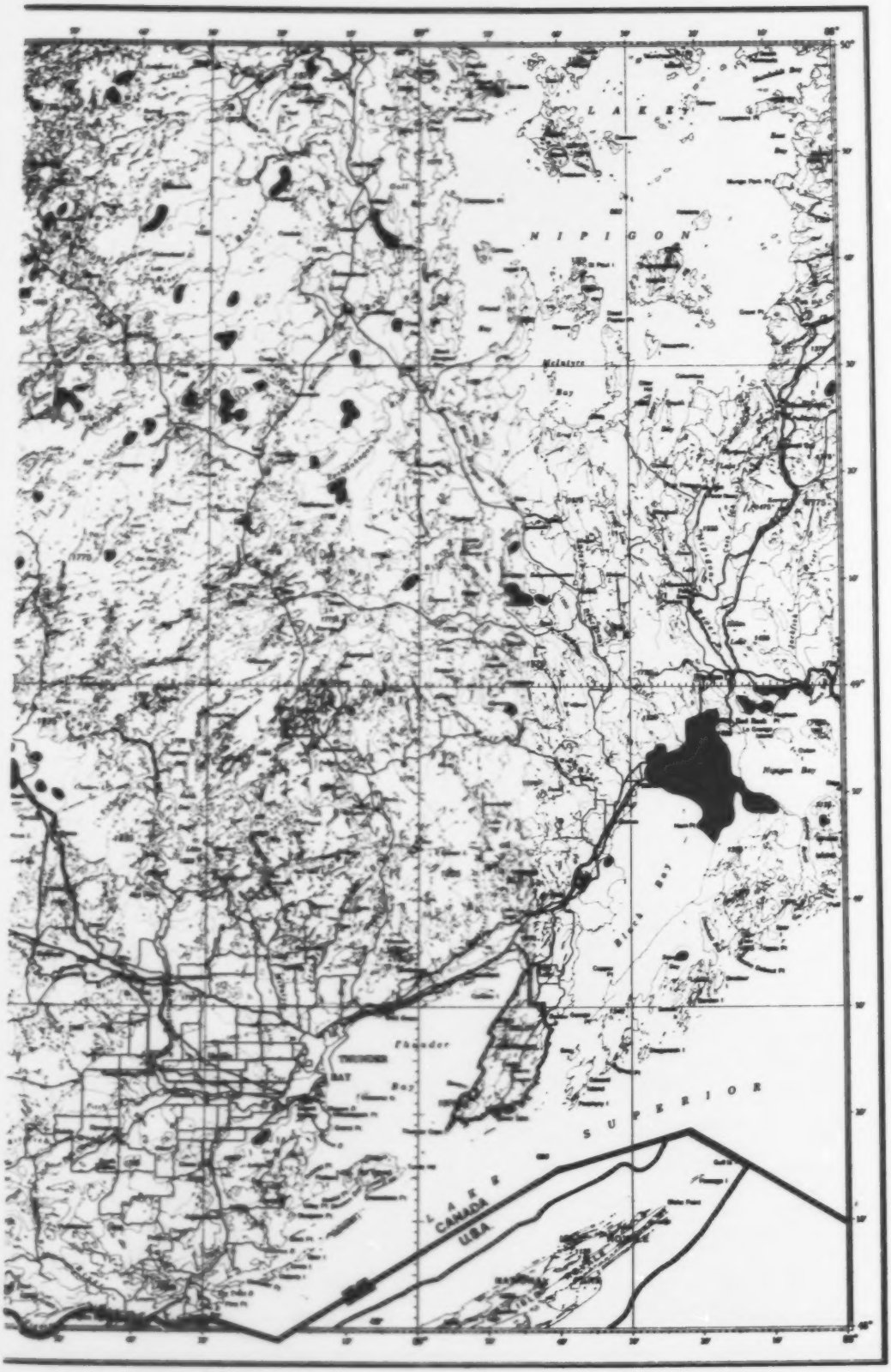


PLATE A-17. PEATLAND DISTRIBUTION FOR NTS AREA 52 SE, THUNDER BAY.


L A K E
N I P I G O N
Nakina
Bay
Thunder
BAY
Bay
Black Bay
S U P E R I O R
CANADA
USA

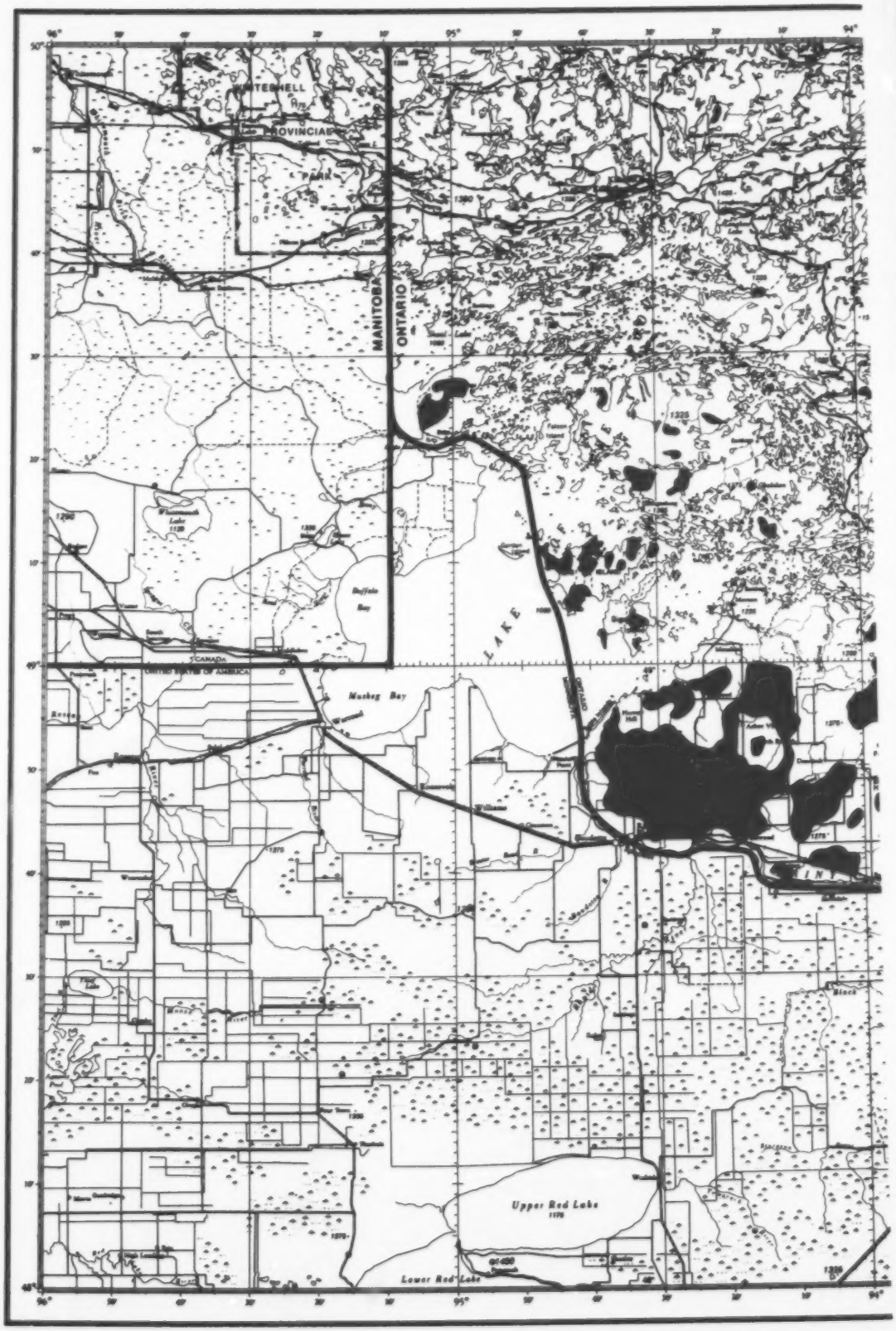
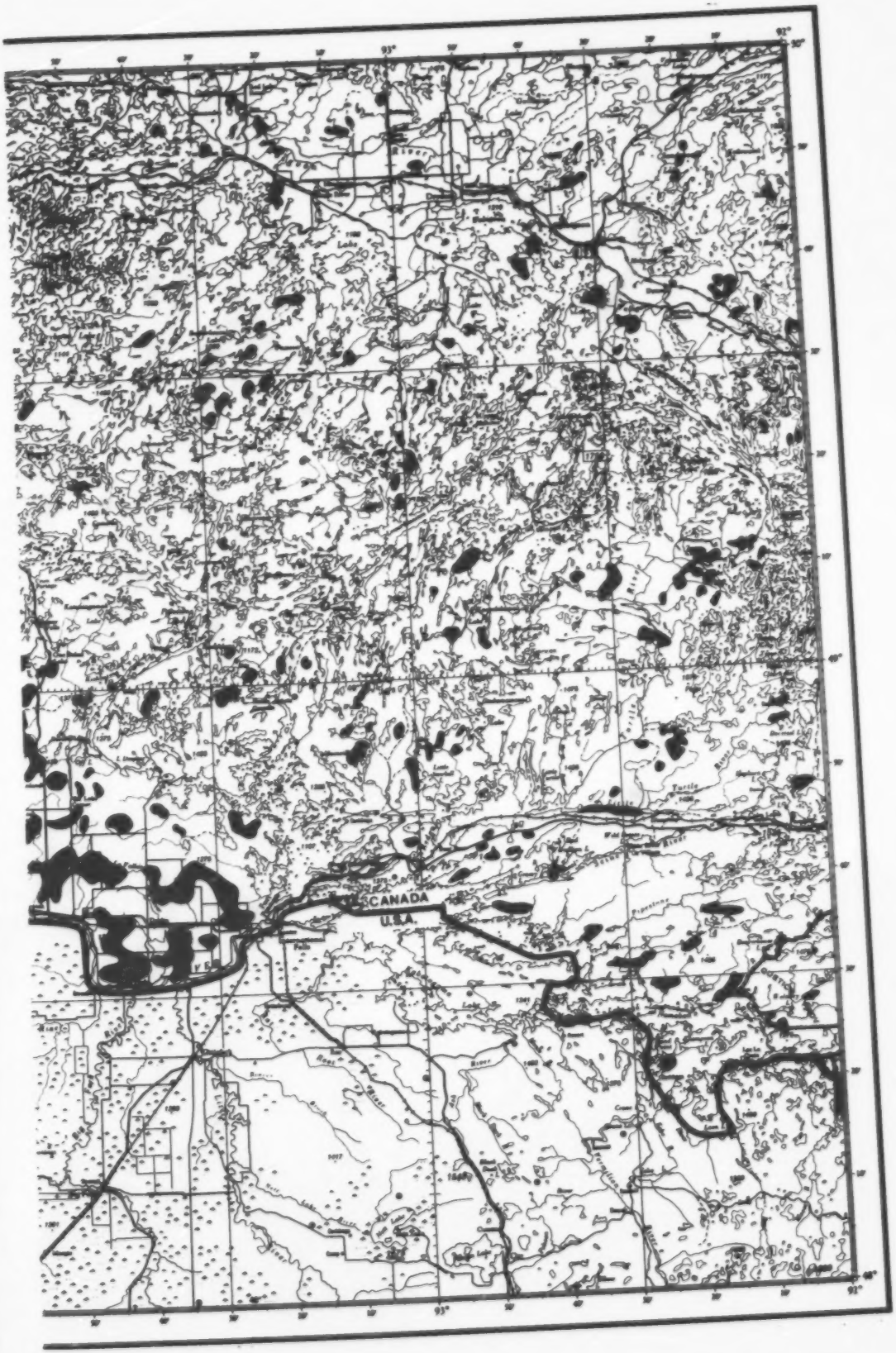


PLATE A-18. PEATLAND DISTRIBUTION FOR NTS AREA 52 SW, KENORA-FORT FRANCES.


CANADA
U.S.A.

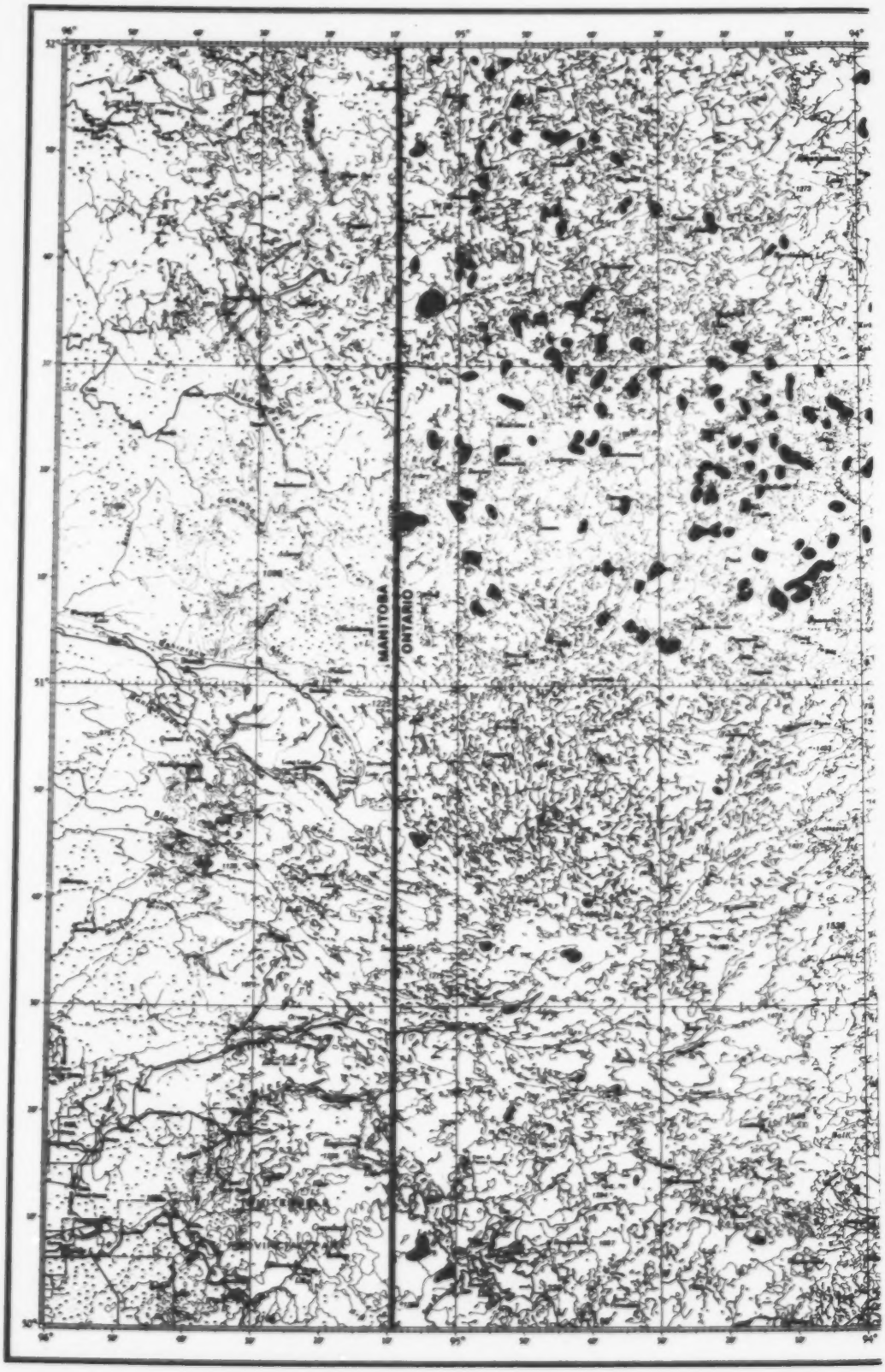


PLATE A-19. PEATLAND DISTRIBUTION FOR NTS AREA 52 NW, ENGLISH RIVER.

TROUT LAKE
1624
Oak Lake

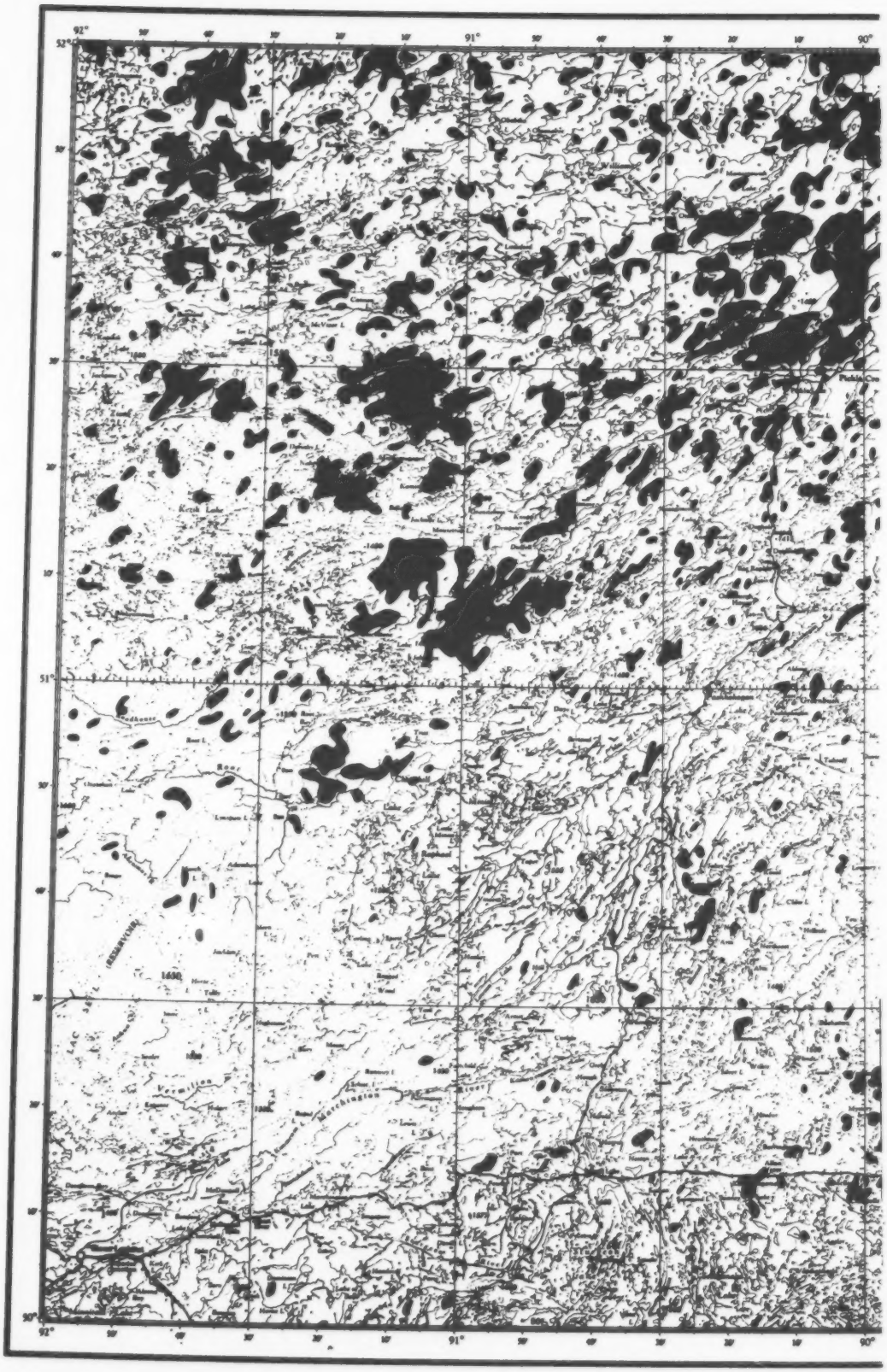
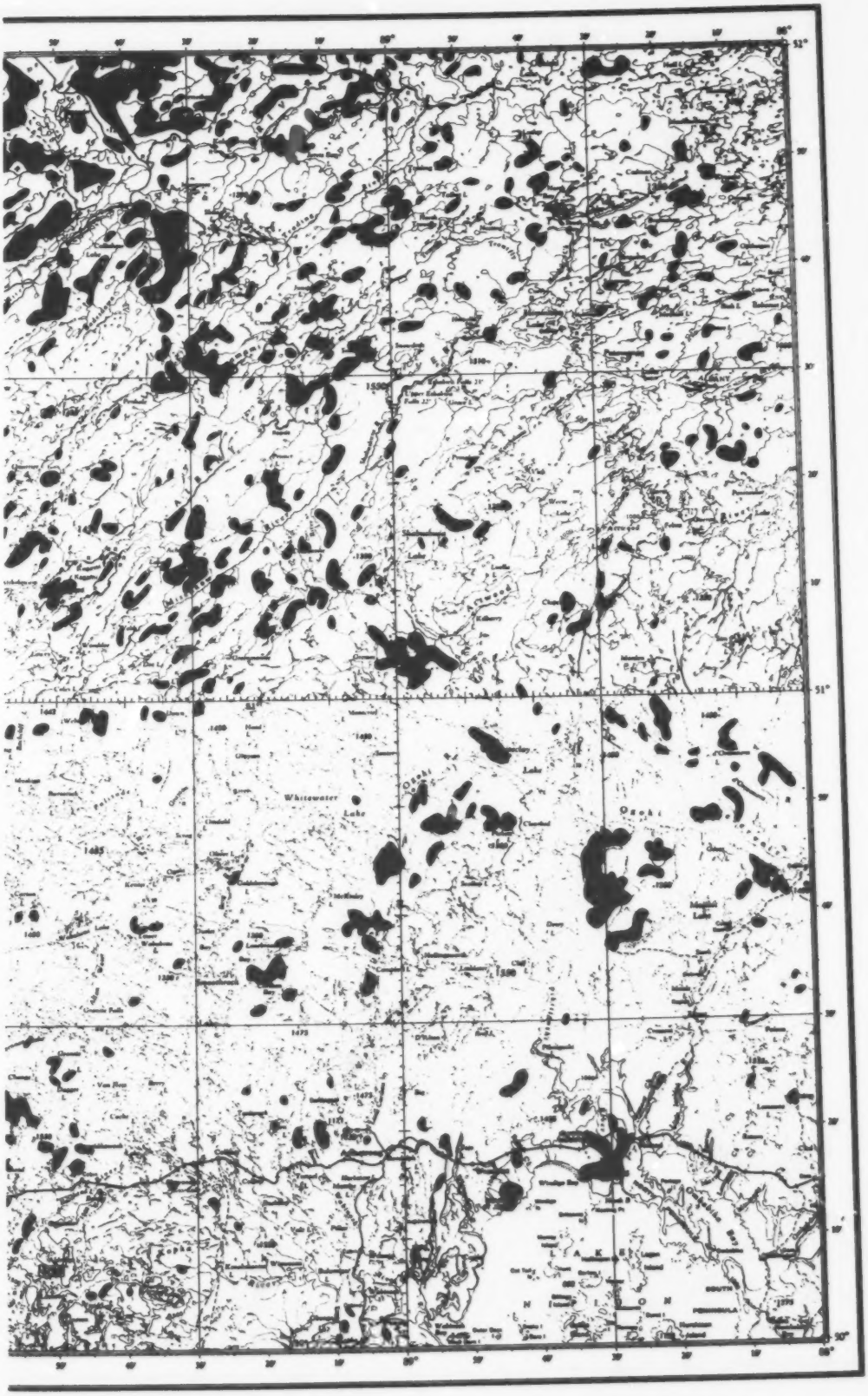


PLATE A-20. PEATLAND DISTRIBUTION FOR NTS AREA 52 NE, PICKLE CROW - ARMSTRONG.


Whitewater
Lake

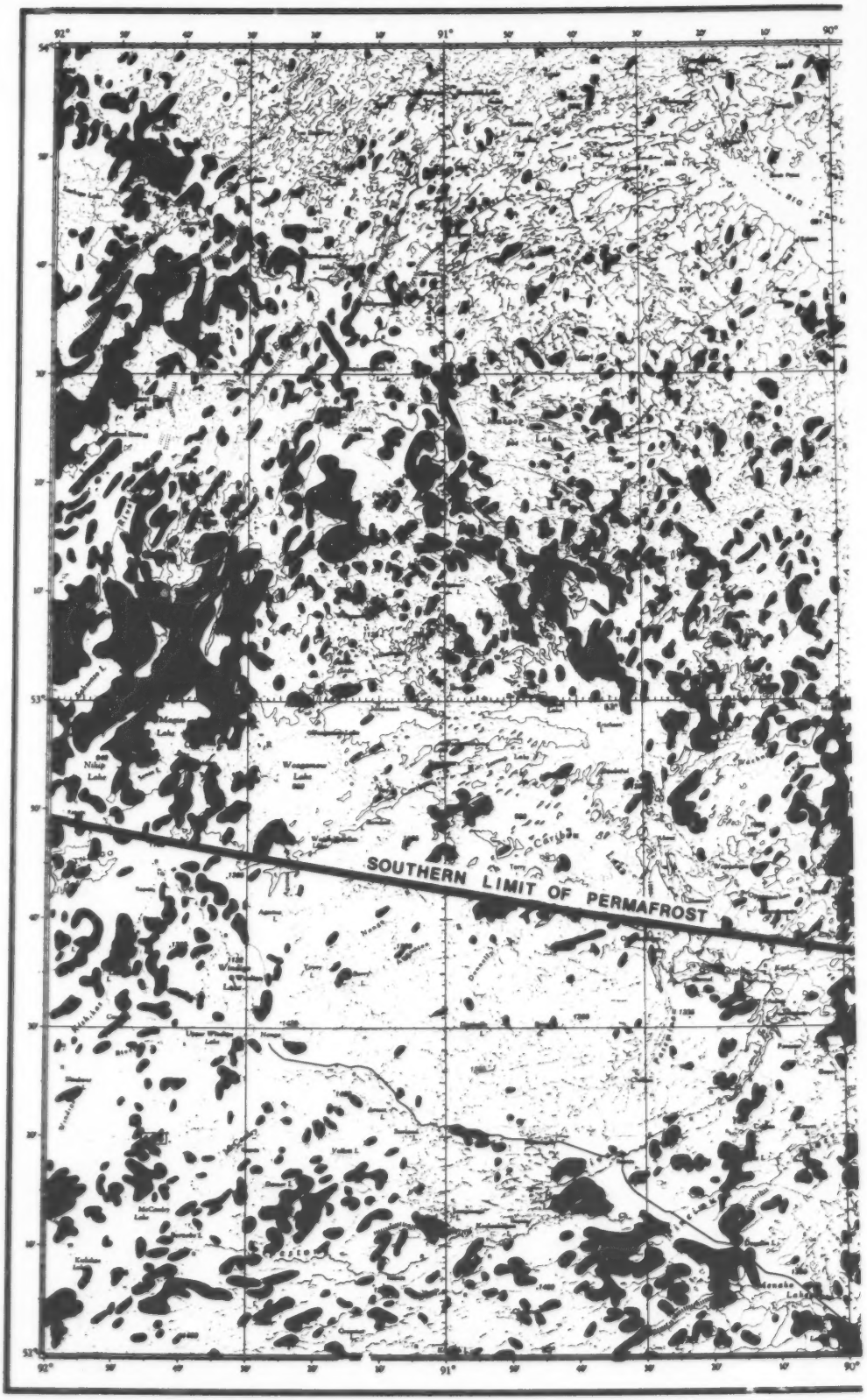
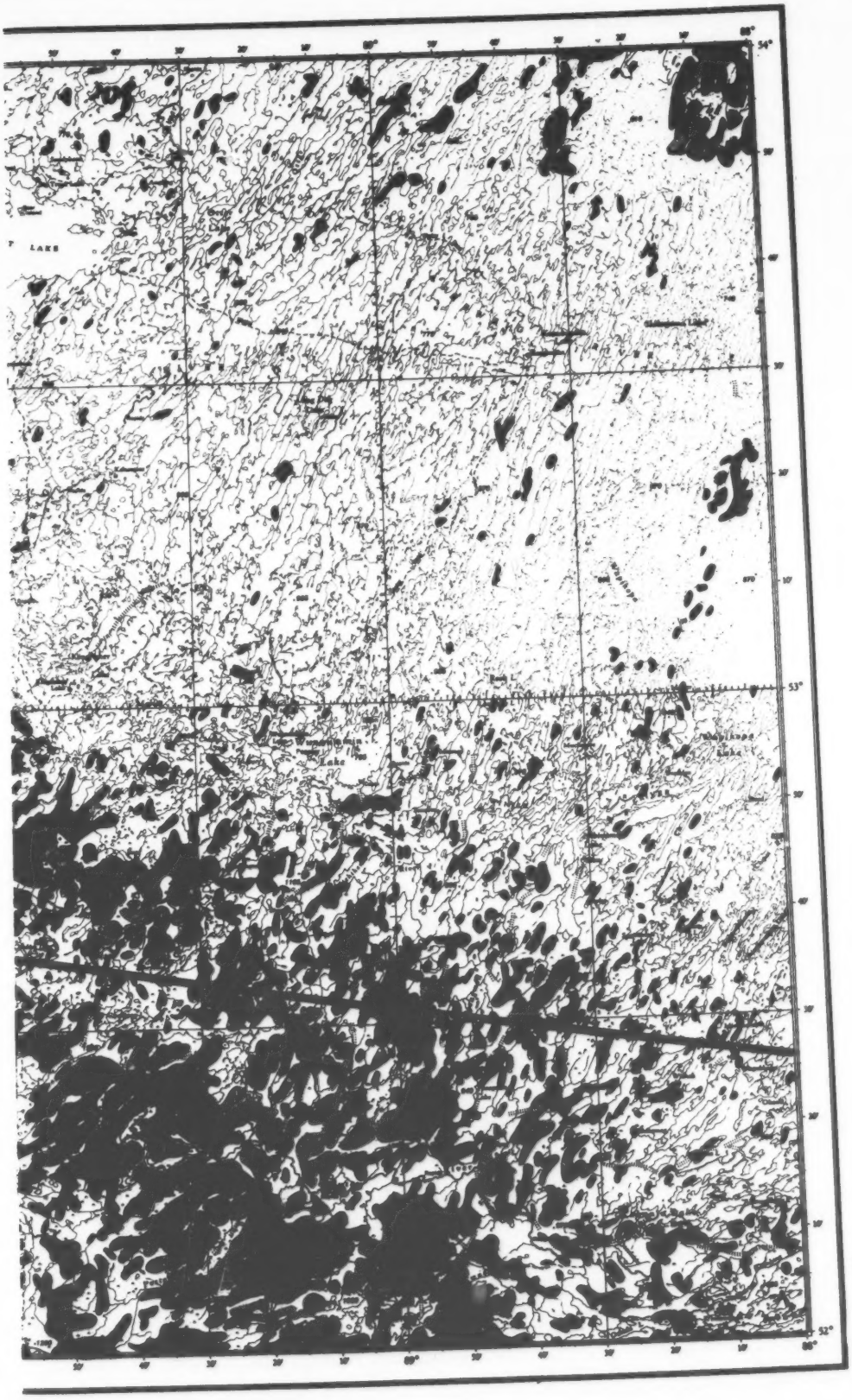


PLATE A-21. PEATLAND DISTRIBUTION FOR NTS AREA 53 SE, WUNNUMMIN LAKE.



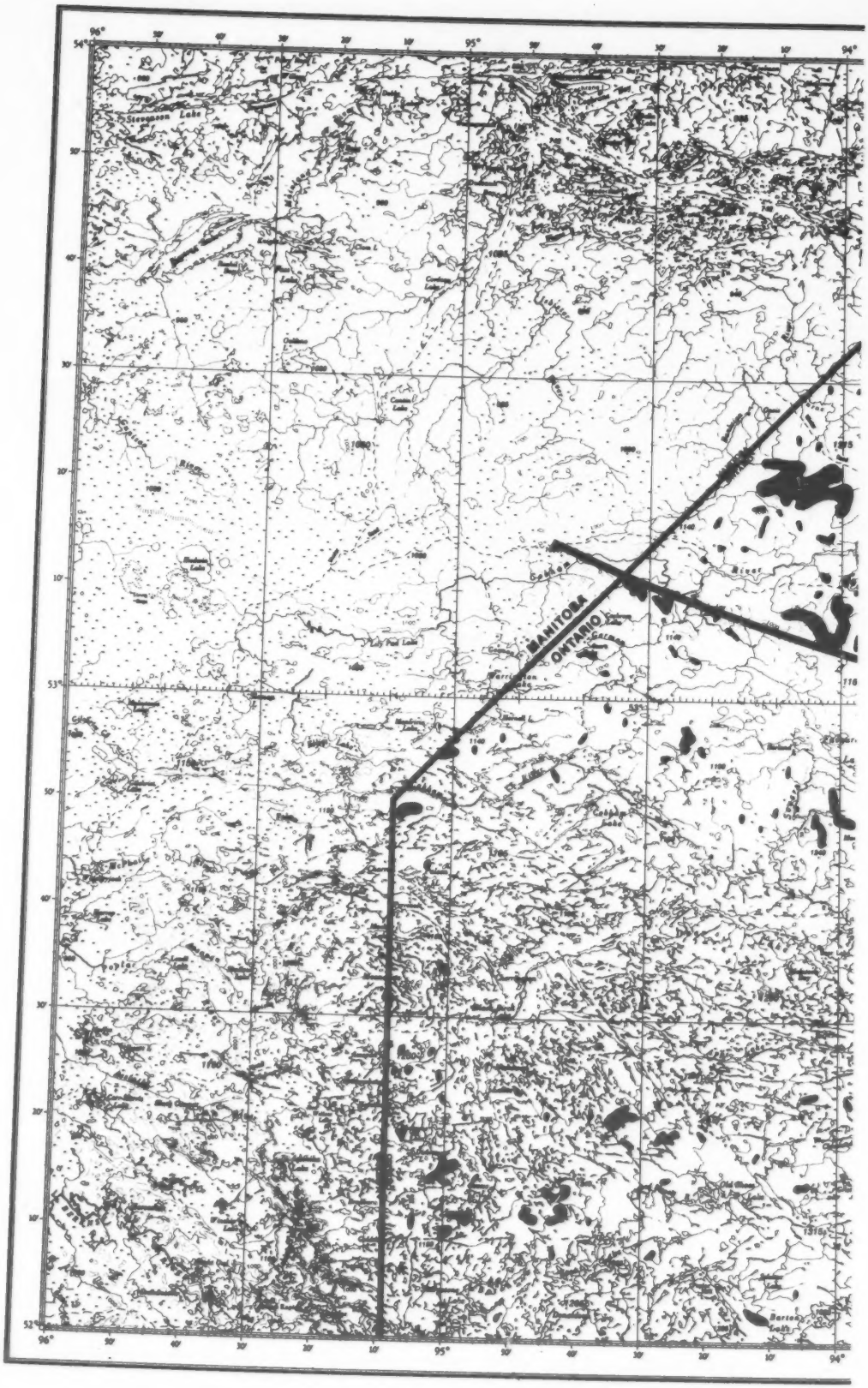
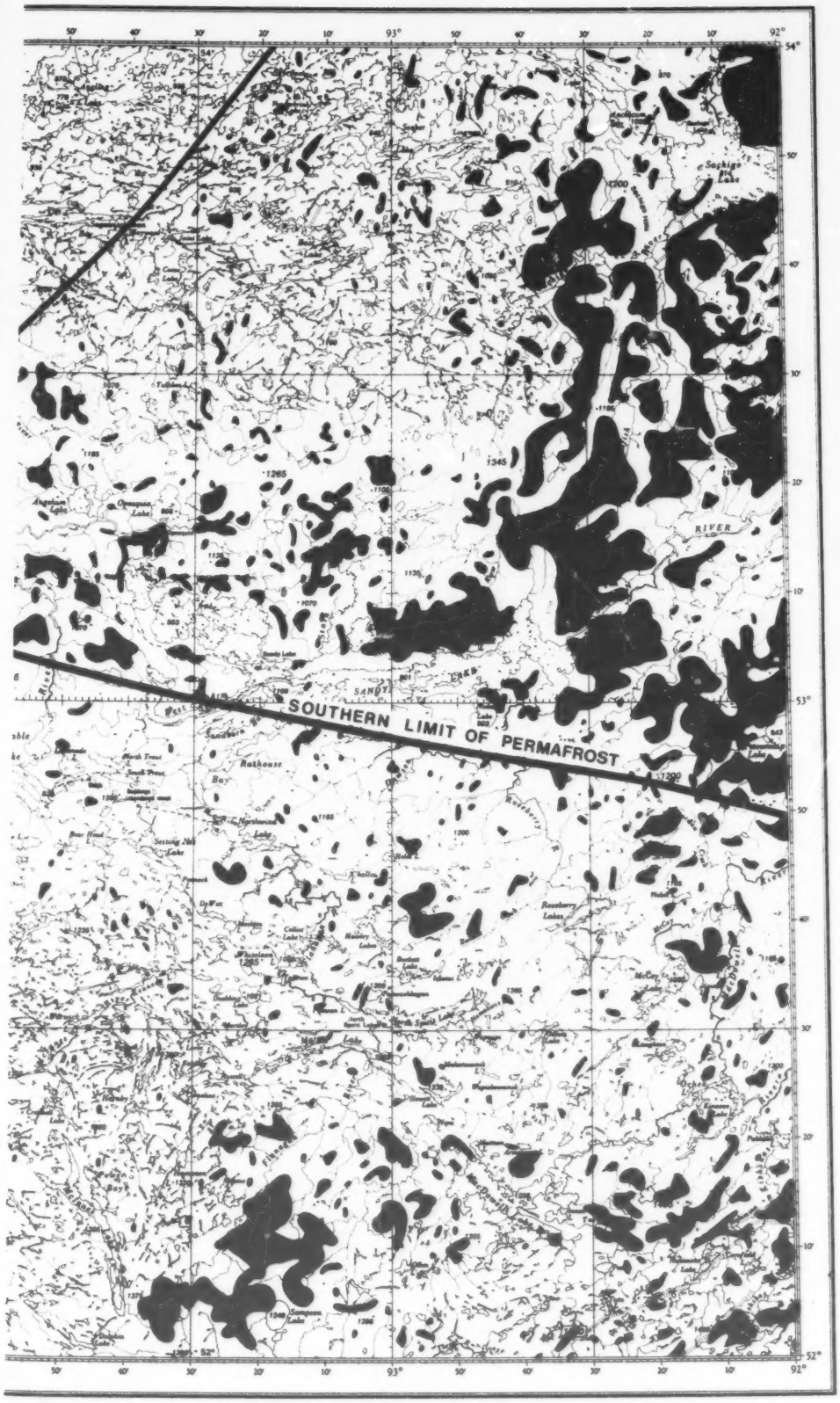


PLATE A-22. PEATLAND DISTRIBUTION FOR NTS AREA 53 SW, BERENS RIVER.


SOUTHERN LIMIT OF PERMAFROST

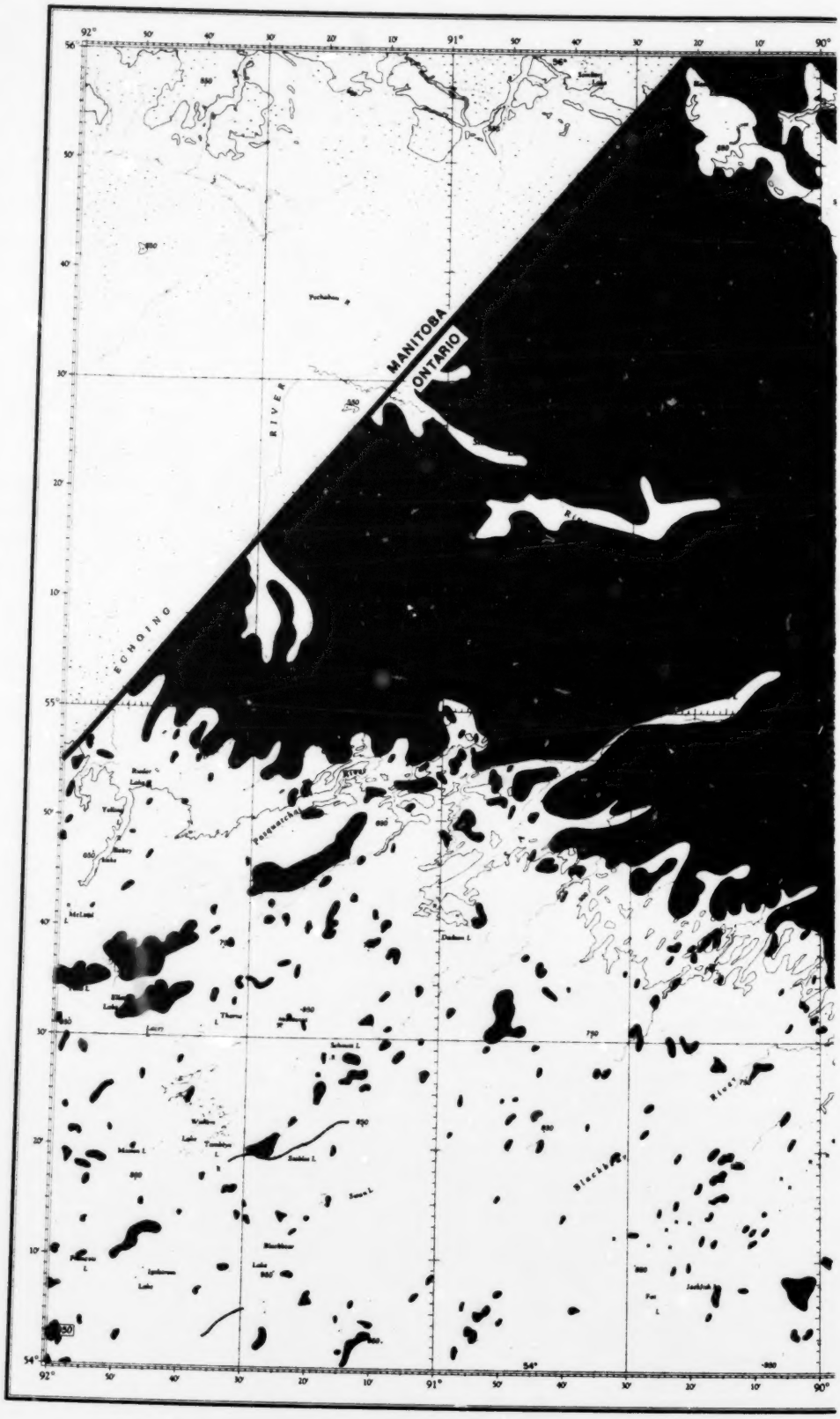
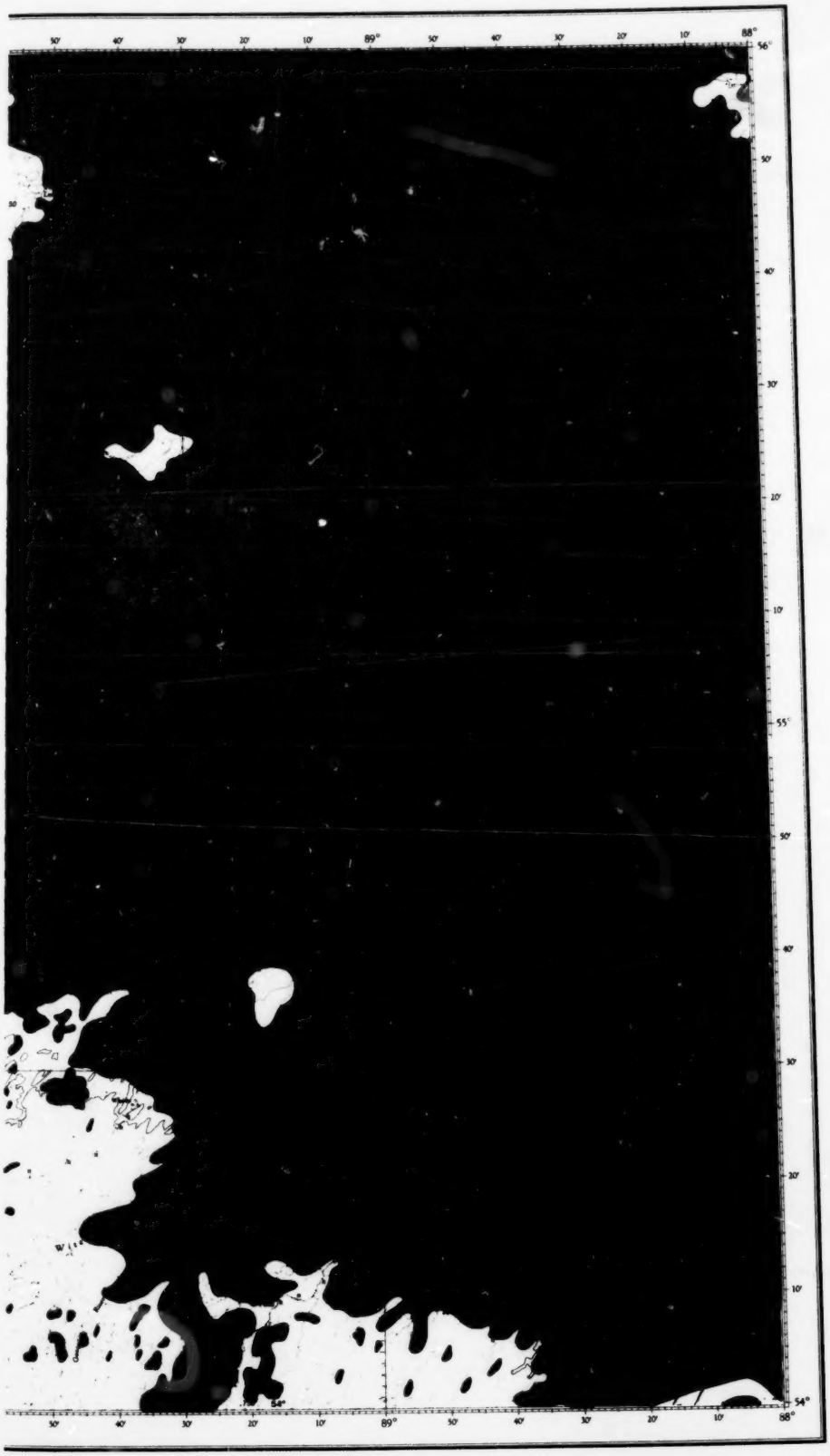


PLATE A-23. PEATLAND DISTRIBUTION FOR NTS AREA 53 NE, SEVERN RIVER.



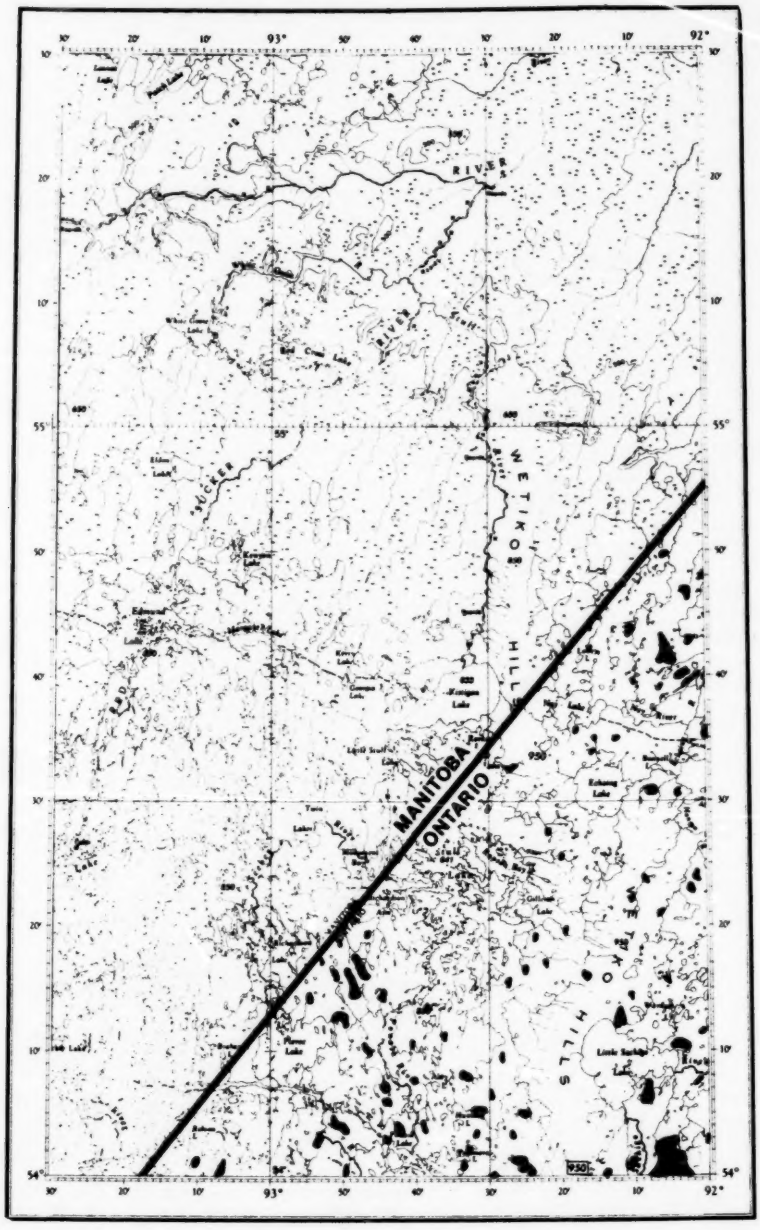
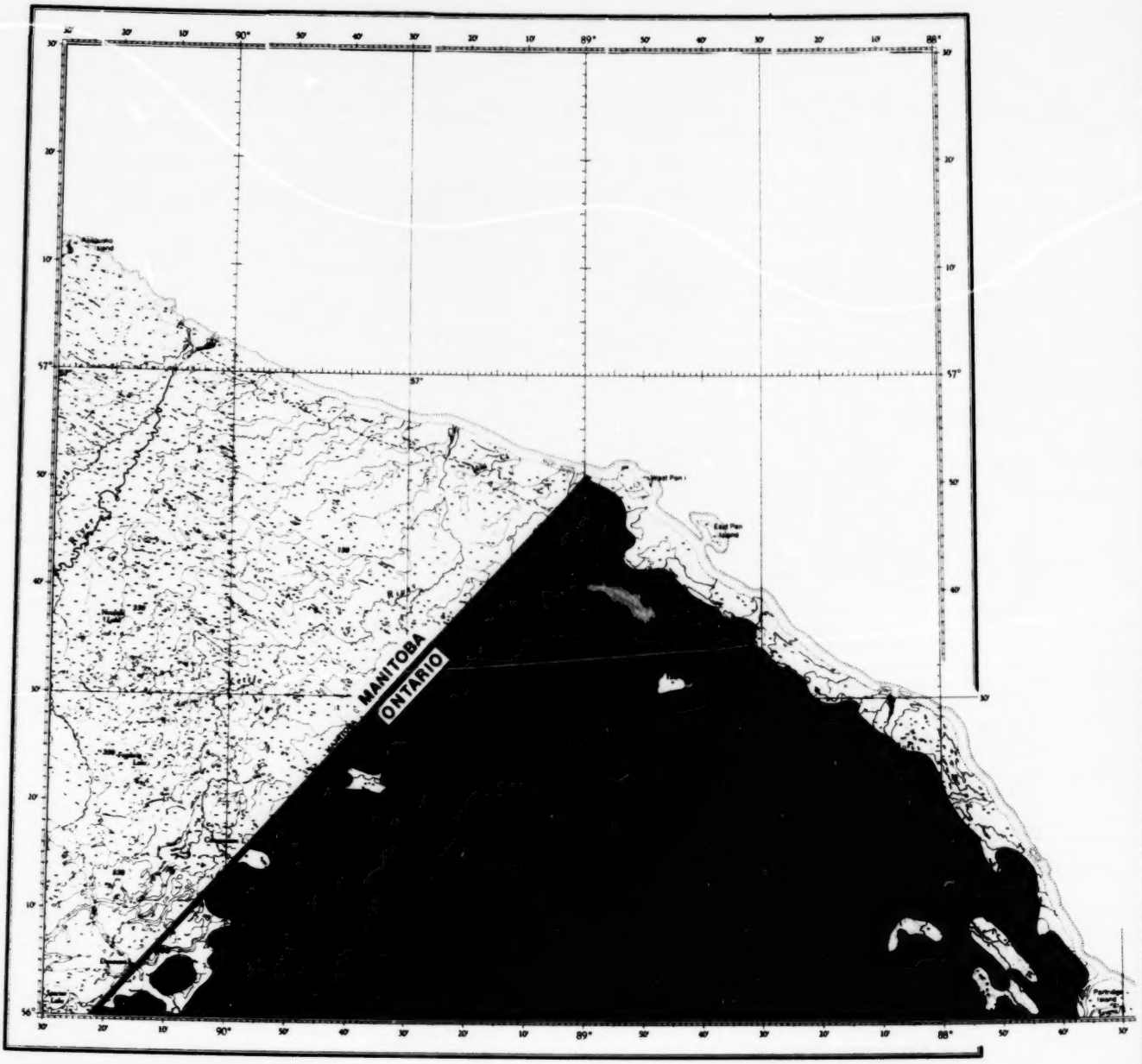


PLATE A-24. PEATLAND DISTRIBUTION FOR NTS AREA 54 SE/53 NW, CAPE TATNAM/GODS LAKE.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APPENDIX B
Notes On Peat-Fired Power Stations in the U.S.S.R.

B.1 INTRODUCTION

The following are notes and information taken during the course of discussions with engineers recently arrived from the U.S.S.R. who have had considerable experience with peat-fired power stations, including operations and project management.

As mentioned earlier (Part 2) the U.S.S.R. has large reserves of peat and extracts by far the largest annual amount of peat.

B.2 PEAT MINING*

Peat is extracted in the U.S.S.R. by milling (more than 95% of total commercial extraction), excavation, and the deep-pit method. The prototype of the excavation method was the elevator method, by which about 1.3 million tonnes of lump peat was extracted in 1913. Elevators transported raw peat from an open pit, then mixed and pressed it into bricks. The drying, collecting and loading operations were performed manually. A hydraulic (hydro-peat) method of extracting peat, completely mechanized, was developed in the 1920's and operated until 1962.

The cutting and elevator methods of extraction, which relied on manual labor, were used until the 1920's. The hydraulic method of extracting peat was developed in the early years of Soviet power by R.E. Klasson and V.D. Kirpichnikov. Peat works were built in Shatura, Moscow Oblast, after the April 21, 1918, decrees of the Council of People's Commissars On Peat Fuel Works. The GOELRO plan called for the construction of five large regional power plants to be operated on peat, and research on the country's vast peat deposits was begun. In the late 1920's production processes and complexes were developed, and the excavation and milling methods of extraction were introduced. The milling method was completely mechanized by the end of the 1940's.

The method is completely mechanized and requires less labor and consumption of metal and energy than other methods. The principal operations include milling the top peat layers of a deposit to a depth of 25 mm, drying the milled peat, and gathering the finished product in the form of crumbs. A layer takes one to two days to dry. There are 20-28 such cycles in a season and approximately 40-50 cycles when the pneumatic method of collecting the peat is used. The milling may be done with harrows, cultivators, or drum-type milling machines hooked to tractors. Peat extracted by peat machines is kept in piles in the field for an average of approximately six months. The most effective way to store peat and prevent spontaneous combustion is to insulate the piles from the air with a layer of wet peat. The use of a polymer film for this purpose was introduced in 1975.

The deep-pit method of extracting lump peat is used to supply nonindustrial needs. In this method the peat is dug from narrow trenches, processed, and pressed into bricks. The peat bricks are laid out on the field to dry, and the trenches are packed down by the extracting machine.

B.3 PEAT PRODUCTION*

Peat is most abundant in Western Siberia and the Northwest European USSR; these regions contain almost 90 percent of the country's total peat reserves. In the USSR, 1.09 million tons of peat were extracted in 1918, 5.3 million tons in 1928, 32.1 million tons in 1940, 27.1 million tons in 1946, 59.2 million tons in 1965, and approximately 90 million tons in 1975 (all figures for peat with 40 percent moisture content). At the recent Peat Congress (6th International) held in Duluth, Minnesota in 1980 (proceedings unpublished 1981), Mr. B.N. Sokolov stated that total peat production had reached 180-200 million tonnes and that "in spite of the development of power engineering, based on atomic energy, mineral coal and hydro resources, the demand for peat as an energy-producing fuel is not decreasing and the significance of peat-fired power stations in some regions of the country is great."

*Excerpts from a Soviet Encyclopedia.

B.4 PEAT-FIRED POWER PLANTS

B.4.1 GENERAL

By 1940 all the electric power plants in Yaroslavl, Ivanovo, Vladimir, and Kalinin oblasts and in Byelorussia were operating on peat fuel. Peat constituted 19 percent of the fuel used by facilities under the raion board of power system management in Moscow Raion, 40 percent in Leningrad Raion, and 65 percent in Gorky Raion. In 1974, 79 power stations with capacities rated at more than 4,000 megawatts were operating on peat. Despite the overall increases in the amount of peat extracted, the percentage of peat in the fuel balance dropped to 1.4 percent in 1975. Apparently, in 1980 this figure had increased in excess of 6,000 MW, but this has not been continued at the time of writing. Plate 3-1 shows the location of a number of peat-fired plants in the USSR, including the most recent, large 630 MW stations.

B.4.2 RIGA, LATVIA PEAT-FIRED STATION

This station was built in the early 1950's, and is of 150 MW capacity. In the Riga area, most bogs are now empty within a 30 km radius and peat is currently transported from up to a 140-150 km distance and further. The station is only 20-50% fired on peat now. The nearby bogs have been turned over to agriculture and make excellent grazing area for cattle. For the first few years, after completion of the peat mining operations, tree stumps etc. had to be removed but the area now is, apparently, aesthetically quite pleasing.

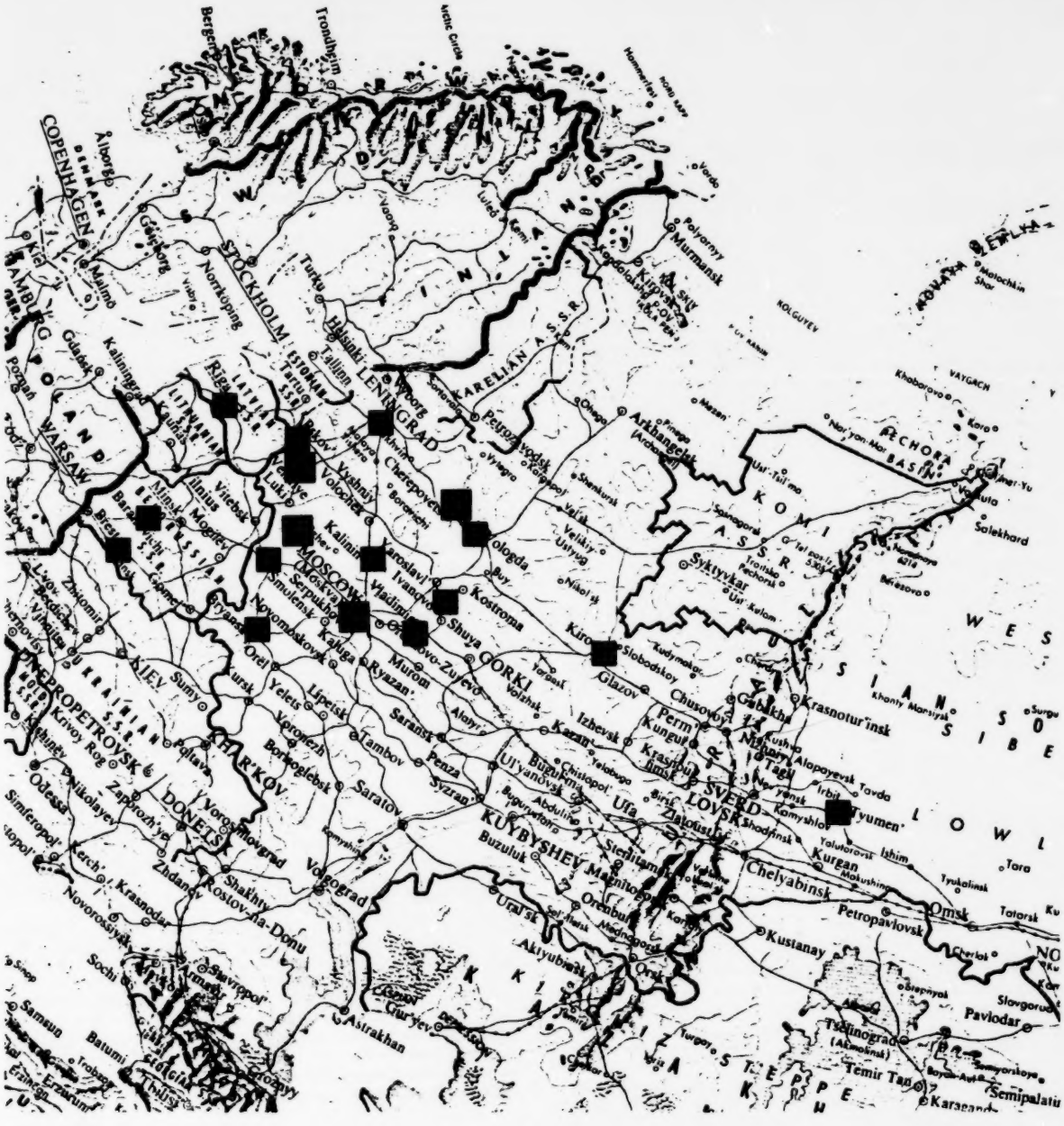
B.4.3 NEW PEAT-FIRED POWER STATIONS

The following is a listing of most recent large peat-fired stations constructed in the U.S.S.R. Some additional detail is presented for the Smolensk station.

	Size	Start Construction	1st Unit Fired
Smolensk (near Moscow)	630 MW	1970	1977
Pskov (near Leningrad)	630 MW	1972-3	1982
Shatura (near Moscow)	630 MW	1968-9	1976-7
Tcherepovets (near Leningrad)	630 MW	1968-9	1976

Each station consists of 3 units, a unit comprising boiler, turbine and generator, of 210 MW each. Apparently, the first units are to be completed in 1982 and the second units are under construction. It is said that electrical energy from peat is the cheapest in the USSR except for hydro-electric energy, and that the cost of peat represents about 70% of the total cost per kw output.

It appears that due to the many mechanisms required for peat-fired stations, the Soviets prefer to build the larger units. Peat-fired stations are small in Soviet terms since new coal-fired units are typically in the 3-4,000 MW range.



LEGEND

- 5 TO 200 MW PEAT FIRED POWER STATIONS
- 630 MW (3x210) PEAT FIRED POWER STATIONS

PLATE B-1. PEAT-FIRED POWER STATIONS IN THE USSR.

SMOLENSK POWER STATION

PEAT REQUIREMENT. Peat comes by rail from three mines and totals 4,300,000 tonnes/year broken by haulage distance into the following:

Mine	km
1,300,000	15
1,500,000	60
1,500,000	120
4,300,000	

HANDLING SYSTEM. Railcar capacity ranges from 40 to 80 m^3 each. The unloading facility is approximately 350 m long and can service 52 cars. One train unloading time is about 50 minutes. Daily fuel consumption is about 18,300 tonnes. A defrost facility is available for cars in winter. A 3 day's emergency reserve was located 300-500 m distance from the unloading facility and was connected by conveyor to the main fuel supply line. A 2 weeks fuel reserve was located at the nearest peat mine.

BOILER PLANT. The boiler was a two chamber (casing) type. Pyramidal-type fuel bunkers caused peat arching. Bunker storage was about 3 hours fuel consumption. Stabilizing of the peat flow was achieved by providing an additional oil pilot burner. The oil supply facility consisted of 3 tanks, total of 6,000 tonnes oil.

Fly ash and bottom ash removal was of wet slurry type. The wet ash removal system caused a lot of operational problems due to $CaCO_3$ deposits in pipelines and pumps. Fly ash was collected in multi-cyclones, and collection efficiency was about 94%.

Electrostatic precipitators were considered but due to explosion risk, their installation was cancelled (e.g. flame-out and raw peat goes to precipitators).

After the ID fans, a 150 m high stack was installed with 18.0 m at the top outlet for 3 units. A ground level concentration of dust, at 20 stack heights distance, of 0.5 mg/m^3 was the environmental standard.

B.5 DESIGN STANDARDS

The following are some excerpts taken from USSR Government Standards for Building and Design of Boiler Houses. These do not apply to large power stations but are for industrial power stations (up to 150 tonne fuel per hour) using peat for firing.

B.5.1 PEAT PILES

- not to be greater than 150 m in length
- not to be greater than 30 m in width
- not to be greater than 7 m in height
- slopes not to be less than 40°

Piles are to be constructed in couples (side by side) with 5 m separating each pile and couples of piles separated 30 m. 45 m spacing to be left between ends of piles. Storage shculd be not more than for 7 days power station supply, if using trucks.

B.5.2 HANDLING

If the outside temperature goes below 20°C all fuel supply handling equipment (belt conveyors) should be enclosed. Storage bin walls should not be less than 60° to horizontal, transfer chutes not less than 65°, belt conveyors not less than 20°. All bins should have corner plates welded in place (to avoid hang-ups). The location of unloading peat for handling to the boiler house and the location for handling peat to storage should be together (economics).

The unloading station should have 2 unload hoppers, 2 apron feeders, 2 belt conveyors (to the power station).

An electromagnet should be installed before the boiler bunkers. A device for clearing off stumps and roots should also be installed.

B.6 OTHER USES OF PEAT*

Research on the use of peat in power technology was carried out in the 1950's. The possibility of using peat from a single deposit simultaneously for agricultural and industrial purposes fostered a new trend in peat utilization in the USSR – the combination use of peat – made possible by the varied properties of the different species types of peat. For example, weakly decomposed high-moor peat contains 40-50 percent carbohydrates; humic acids constitute 50 percent or more of strongly decomposed peat. Some peat types are rich in bitumens (2-10 percent). Weakly decomposed high-moor peat has a high water- and gas-absorbing capacity and a low coefficient of thermal conductivity.

Strongly decomposed peat finds varied applications in agriculture. It is used to prepare composts, mixtures containing mineral fertilizers and lime, and peat-mineral and peat-mineral-ammonia fertilizers. Peat containing vivianite is used as a phosphorus fertilizer, and peat with lime as a lime fertilizer. Low-moor peat added in large quantities (500 tons per ha or more) helps condition sod-podzolic soils and improve their physical and chemical properties.

Peat-humus bricks and greenhouse soil mixtures are used with other constituents, including manure and mineral fertilizers, to grow vegetables and flowers; undecomposed peat serves as a biological fuel. Well-aerated and thoroughly decomposed peat is used to mulch seeded fields. High-moor peat provides good bedding for cattle and poultry. Some types of strongly decomposed peat contain substantial quantities of bitumens and are used to produce waxes. The world's only plant for the production of alcohol and furfural from weakly decomposed peat is located in Leningrad Oblast. Heat- and sound-insulating peat slabs and garden pots made from peat are also produced. Activated charcoal is produced from peat in the Federal Republic of Germany, the Netherlands, and the USSR. Pressed peat briquettes are used in the USSR and Ireland for nonindustrial purposes.

Advances in the technology of processing peat are being made in two directions. The first is based on isolating individual constituents – bitumens, humic acids, carbohydrates, and so on. These constituents are extracted with insignificant changes in the original material in the form of ready products or as raw material for further processing. The second trend involves the thorough decomposition of peat and the conversion of peat into completely new substances. These substances are the products of thermal and oxidative degradation, hydrogenation, and other processes.

*Excerpts from a Soviet encyclopedia.

GLOSSARY

Airform Pattern. An arrangement of shapes, apparent at a particular altitude, which is characteristic for significant terrain entities and their spatial relationship and thus useful in the application of aerial interpretation.

Bog. Peatlands in which sphagnum peat predominates; can be tree covered. Usually the peat layer is thick. Generally acid and poor in nutrients. This term is sometimes used loosely to refer to ormbrogenic (raised bog) peatlands.

Bulk Density. The total weight (including solid material and any contained water) of a material per unit volume (including voids)

Confined Peatland. A peatland confined to a topographical depression or otherwise limited in size. Occurs commonly in the rocky Precambrian Shield Area.

Continuous Peatland. *See unconfined peatland.*

Energy Peats. Peats with low ash content, high bulk density and high degree of humification.

Eutrophic. Of high nutrient content. Conditions in which a certain kind of peat was formed referred to as eutrophic peat. Condition also where peatland vegetation is very varied due to high nutrient content as opposed to oligitrophic conditions.

Fen. Usually a sedge covered open peatland. Sedge peat predominates. Less acid than peat in bogs. Misotrophic-eutrophic.

Fenno. Consists of a dominantly fibric layer, derived from rushes, reeds, sedges throughout the middle and bottom tiers. (Also, see Fibric and Tier).

Fibric. This is the least decomposed of all of the organic soil materials. It has large amounts of well preserved fibre that is readily identifiable as to botanical origin. Fibric, according to J.H. Day's classification of Canadian organic soils is a layer which can be a component of a tier. (See Tier).

Gyttja. Swedish folk name (von Post, 1862). Subaqueous humus form, active, muddy, predominantly coprogenic, grey-brown to blackish sediment, rich in organisms occurring in waters sufficiently rich in nutrients and oxygen, containing great quantities of organic food (partly in excess).

Humic. This is the most highly decomposed of the organic soil materials. It has the least amount of plant fibre, the highest bulk density and lowest saturated water content. It is very stable and changes little physically and chemically with time in comparison to the others. Humic, according to J.H. Day's classification of Canadian organic soils is a layer which can be a component of a tier. (See Tier).

Humification, Degree Of. A system whereby the degree of decomposition of peat is determined on a scale from 1 to 10. This method is suitable for field determinations.

Marsh. Shallow very wet eutrophic peatland. Usually grassy and open. Occasionally flooded. Standing or slowly flowing water.

Mesic. This is the intermediate stage of decomposition. This material has intermediate amount of fibre, bulk density, and water content. The material is partly altered both physically and biochemically. Mesic, according to J.H. Day's classification of Canadian organic soils is a layer which can be a component of a tier. (See Tier).

Mesotrophic. Of medium nutrient content. A peatland may be mesotrophic if it displays species which do not require eutrophic conditions but which would not thrive in oligotrophic conditions either.

Minerogenic. A muskeg is minerogenic if it is supplied with nutrients received from the surrounding mineral terrain or from the mineral subsoil (minerotrophic).

Oligotrophic. Poor (oligotrophic) (Greek oligos, "little"; trophos, 'nourishment'): Sites with low nutrient availability and relatively low biological activity, generally formed on base-deficient parent rocks. Designation for peatlands (muskegs) formed of plants in soft waters poor to extremely poor in nutrients. An example of this type is a raised bog. Trees are stunted and the shrub layer is poorly developed. Organic material is little decomposed. Sphagnum peat is characteristic.

Ombrogenic. A muskeg is ombrogenic when it receives all the mineral nutrient matter from the atmospheric water; thus it generally is also oligotrophic (e.g. raised bog).

Paludification. 'Marshifying', 'swampifying', turning of drier land into wet land. More exactly: the process of formation of peatland.

Peat. Partially decomposed plant matter found in peatland. Internationally agreed upon definition still lacking. However, should not contain more than 40% of mineral matter (wet weight).

Peat Formula. A system whereby various aspects, such as peat type, degree of humification, moisture content, fibrosity etc. are given as a formula containing symbols and numerical values.

Peatland. A land covered by peat as peat forming vegetation, and characterized by high water table. Cf. biological and geological peatland.

Peatland, Biological. Land covered by vegetation characterizing peatlands and conducive to the formation of peat. May contain no peat when young or several metres of peat when advanced in the paludification process. Cf. peatland and geological peatland.

Peatland, Geological. Land covered by at least 30 cm of peat. Cf. peatland and biological peatland.

Permafrost. A thermal condition of earth materials such as rock, peat or other looser soils when their temperature remains below 0°C for a number of years, which may be as few as two, or as many as tens of thousands. Permafrost may be continuous when it stretches continuously without breaks over large areas or discontinuous when it is distributed in smaller localized pockets and then often in peaty soil only. According to Brown (1967) the permafrost zone can be divided into the zone at continuous permafrost, and the zone of discontinuous permafrost. The latter is divided into widespread and scattered permafrost. The southern limit of permafrost follows approximately the −1°C average annual isotherm.

Radforth Cover, Classification. A system of letter references whereby the general type, texture and stature of peatland vegetation is described. Consists of 9 basic types (A to I) which may combine to form the cover formula (e.g. EFI).

Sedge Peats. Peats where sedge or related plants predominate. Usually less acid than sphagnum peat. Also have a lower water holding and cation exchange capacity but higher bulk density and degree of humification than sphagnum peats.

Sphagnum Peats. Peats where sphagnum mosses predominate. Characterized by high water holding capacity, high acidity, low bulk density, often low degree of humification and light colour.

Stippioid Airform, Pattern. A descriptive term applied to a 30,000-foot airform pattern. The stippioid condition seems to be constructed of closely applied dots.

Swamp. Wooded peatland with a shallow peat layer. Misotrophic-eutrophic. Water usually flowing.

Terric. Consists of an unconsolidated mineral substratum, or of one continuous unconsolidated mineral layer (with less than 30% organic matter) more than 30 cm thick in the middle or bottom tiers underlain by organic matter. (See Tier).

Tier. In the classification of Canadian organic soils (according to J.H. Day), control sections have three tiers, surface, middle, and bottom. These tiers are in turn composed of one more or layers. (See Fibric, Mesic, Humic, Typic, Fenno and Terric).

Typic. Consists of a dominantly mesic or humic layer throughout the middle and bottom tiers. (See Tier). The control section lacks any terric, lithic, hydric, cryic, cumulo, or limno layers. (Also, see Terric)

Unconfined Peatland. A continuous peatland covering thousands of hectares and not confined to a small depression.

von Post System. Originally system of determining the degree of humification. Later modified and expanded to include other characteristics of peat such as the peat type, moisture content and fibrosity.

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